Industrial QUALITY CONTROL

JULY, 1952 VOL. IX, NO. 1, PART 1

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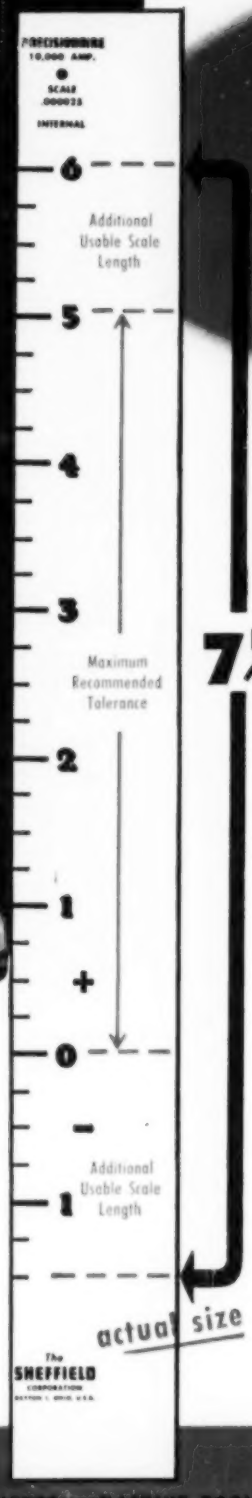

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2,000	.0025	.0013
5,000	.001	.0005
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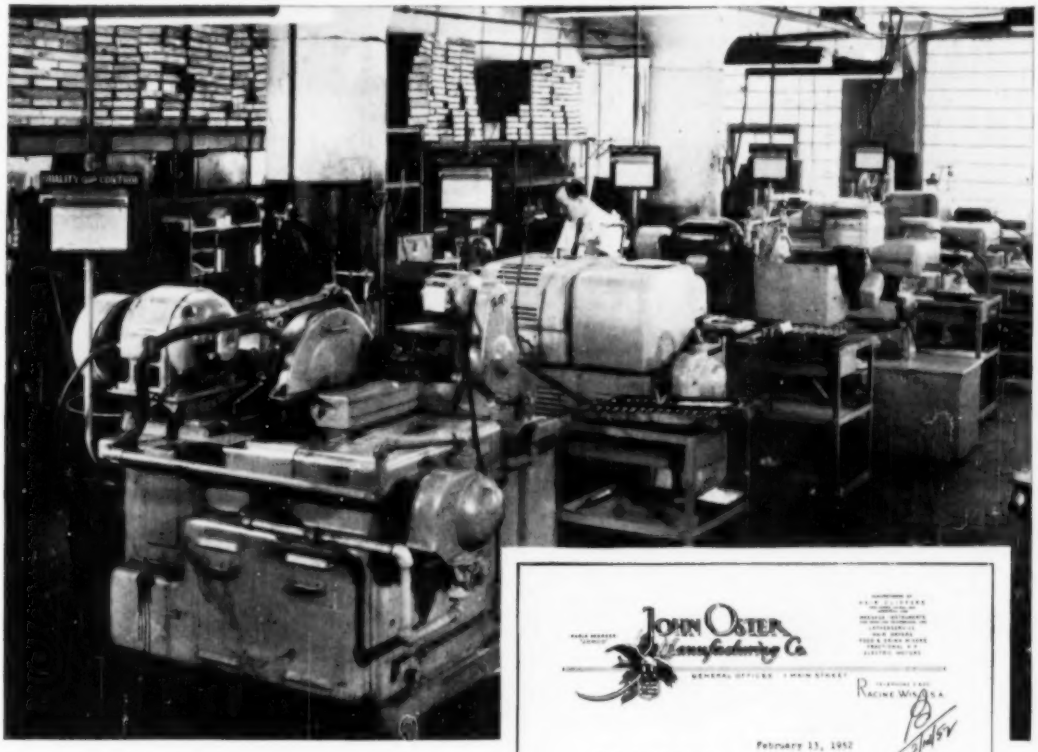

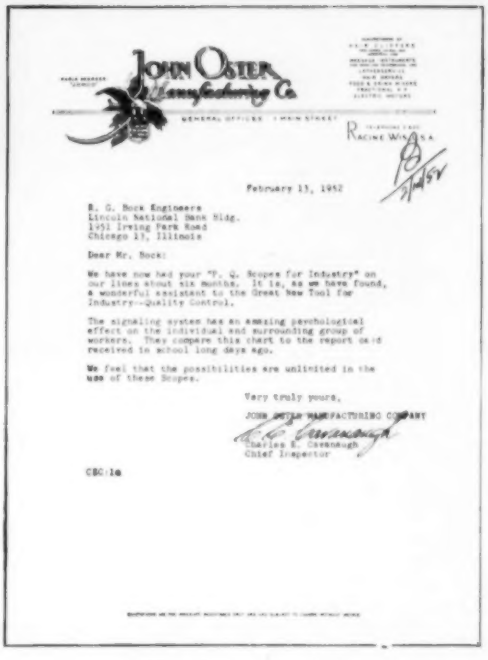

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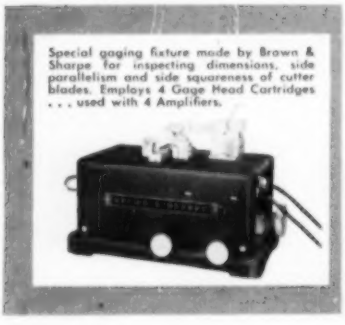
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Industrial Quality Control

Vol. IX JULY, 1952 No. 1, PART I

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TEXTILE DIVISION ANNOUNCEMENT

Mr. W. S. Smith, Chairman of the Textile Technical Committee, ASQC, announces that the National Society has approved the intention to form industry-wide Divisions. This action took place at the annual Board of Directors Meeting of the Society in Syracuse, New York, May 24, President Wade Weaver presiding. The first such Division will be the Textile Division which is expected to be formally activated in August.

This is the culmination of efforts of a Steering Committee for the past few months under the Chairmanship of Mr. John Reynolds, Celanese Corp. of America, Rome, Georgia. The other members of this Steering Committee, which made the action of the Board of Directors possible, were: Mr. R. R. Jones, Bigelow-Sanford Carpet Co., Amsterdam, New York; Mr. E. G. Field, E. G. Field and Associates, Atlanta, Georgia; Dr. R. A. Hefner, Georgia Institute of Technology, Atlanta, Georgia; Mr. G. M. Hailes, Avondale Mills, Sylacauga, Alabama; Mr. E. S. Rudnick, Wamsutta Mills, New Bedford, Massachusetts; Asst. Prof. D. S. Hamby, School of Textiles, North Carolina State College, Raleigh, N. C.

It is expected that this Division will hold national and regional meetings on a periodic basis to further the science of statistical quality control among textile members. Over 60 petitioners, all ASQC members, from throughout the U.S. and Canadian textile industry had been recorded on May 22 as favoring the formation of this Division. It is expected that a special textile supplement to the *Industrial Quality Control* magazine will be issued early in August.

A two-day Textile Quality Control Conference will be held in Clemson, S.C., August 22-23, sponsored by the Textile Technical Committee of ASQC. A similar Conference last year found about 150 in attendance and was agreed by all to have been an overwhelming success. At this year's meeting, it is expected that the Textile Technical Committee will be dissolved and the newly formed Division take over its duties.

Election of Division Officers is to be held prior to the August Meeting by mail ballot. All those ASQC members who have signified their intention of being affiliated with this Textile Division will be eligible to vote. Communications regarding this should be addressed to Mr. E. G. Field, E. G. Field and Associates, 1101 Hurt Building, Atlanta 3, Ga.

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Correspondence is invited on all controversial matters.

General Information

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Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $10.00; for Senior Members, $12.00; for Fellows, $16.00. In each grade, $3.00 of the annual dues are allocated as a subscription to INDUSTRIAL QUALITY CONTROL. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

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Cost of Back Issues

Back issues, comprising Volumes I through VIII are available at $8.00 per volume, including the Index. Individual issues at $1.50 each.

In quest of the "skeleton of speech"

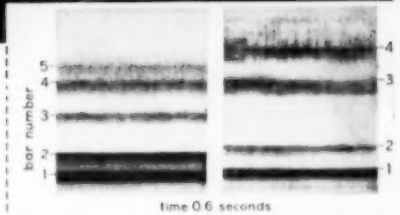
In the famous Quiet Room at Bell Laboratories, this young volunteer records speech for analysis. Scientists seek to isolate the frequencies and intensities which give meaning to words . . . stripping away non-essential parts of word sounds to get the basic "skeleton" of speech.

A child or an adult . . . a man or a woman . . . an American or an Englishman—all speak a certain word. Their voices differ greatly. Yet listeners understand the word at once. What are the common factors in speech which convey this information to the hearer's brain?

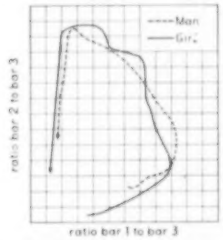
Bell scientists are searching for the key. Once discovered, it could lead to new electrical systems obedient in new ways to the spoken word, saving time and money in telephony.

Chief tool in the research is the sound spectrograph which Bell Telephone Laboratories developed to make speech visible. Many kinds of persons record their voices, each trying to duplicate an electrically produced "model" sound. While their voice patterns are studied, a parallel investigation is made of the way human vocal cords, mouth, nose and throat produce speech.

Thus, scientists at Bell Laboratories dig deeply into the fundamentals of the way people talk, so that tomorrow's telephone system may carry your voice still more efficiently—offering more value, keeping the cost low.



Spectrograms of young girl's voice (right) and man's voice making "uh" sound as in "up." Horizontal bars reveal frequencies in the vocal cavities at which energy is concentrated. The top of the picture is 6000 cycles per second. Pictures show how child's resonance bars are pitched higher than man's.



The word "five." Graph shows ratio of frequency of spectrogram bars. The solid line is for a girl and the dotted line is for a man. Note the similar patterns despite pitch differences. Human hearing extracts the speech sounds from this sort of pattern in the identification of words. Scientists aim at machines that can do the same.

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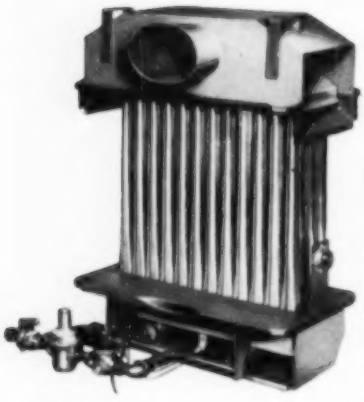

Stainless Steel heat exchanger and burner assembly of Modine gas-fired unit heater.

ENDURO makes new Modine heater more durable, lighter, faster-acting

The use of heat-resisting stainless steel for jet engine exhaust parts gave Modine Manufacturing Company engineers an *idea.* Although gas-fired unit heaters never are subjected to jet engine temperatures or corrosive conditions, they are vulnerable to similar service hazards.

In new Modine models, Republic ENDURO Stainless Steel is used for heat exchangers and burners. From now on, ENDURO construction will *combat these former heater hazards*—corrosion due to gas acids and contaminated atmospheres . . . high-temperature scaling and flaking, which weakened metal walls and clogged burners . . . rusting caused by condensation and atmospheric moisture . . . cracking . . . and rapid discoloration.

In addition, ENDURO has saved 50 to 200 pounds of weight per unit by permitting lighter gauge construction of exchangers and burners. And, with metal mass reduced, tube warm-up lag is minimized. Tests show that the new units actually deliver heat *within 5 seconds* of the thermostat's signal.

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Some Basic Concepts of Quality Control*

GEORGE D. EDWARDS

Bell Telephone Laboratories

I ASK you to consider with me for a few minutes some basic concepts of Quality Control.

In doing this, let's move far enough away from the individual trees, so that we can take a good look at the woods.

Why Quality Control in the first place?

Because we want Quality.

And what is this abstract thing which we call Quality, and which we want?

Well, it might be described as the net resultant of the combined functional, operative or other attributes and capabilities of the material, or article, or gadget, with the quality of which we are concerned.

I like to think of this net resultant as the Overall Quality of the gadget. We might write it as:

$Q = F(Y_1, Y_2, \text{-----}, Y_i, \text{-----}, Y_n)$

where the Y's are the several functional or other attributes and capabities of the gadget. These Y's might be thought of as partial qualities of the gadget.

The function F here, takes care of the fact that these partial qualities are not necessarily directly additive. Many of them will add vectorially, and some may be functions of others.

Now let's take a little closer look at these Y's themselves, which I have called partial qualities. Examples of them would be:

the odor of a perfume;
the flavor of a strawberry jam;
the number of times a cash register will operate without error, or with error justifying repair, before it is cheaper to turn the register in for a new one;
the thermal content of a fuel gas in B.T.U. per cu. ft.
the gasoline consumption of an automobile in gallons per mile of average driving;
and so on.

You will note that I have mentioned only a single illustrative Y, or partial quality, for each of these materials, or articles, or gadgets; whereas each of them would actually have a considerable number of such partial qualities.

Other Y's for the strawberry jam, for example, in addition to the flavor which I mentioned, might be:

the percentage of preservative it contained;
the percentage of water content;
the color;
the uniformity in size of the strawberries in it;
and so on.

Now obviously, some of these partial qualities, such as the water content of the jam, or the thermal content of the fuel gas, can readily be measured in quantitative terms. Others, such perhaps as the odor of the perfume, or the flavor of the jam, may be expressible only in terms of qualitative differences from arbitrary standards of comparison. Some may be measurable with even less precision than this.

At any rate, the non-quantitative nature of many of these partial qualities, and the complex relationship which many of them bear to our overall estimate of quality, Q, will generally make it quite fruitless for us to spend any time in attempting to determine the exact form of our function F. Our best move is to attempt to simplify our expression for Q as much as possible.

So we first eliminate from consideration all of the Y's, or partial qualities, in which even pretty wide variations will obviously have little if any effect on our evaluation of the overall quality Q. One example of a partial quality which might possibly be eliminated in this way, might be the uniformity in size of the strawberries in the jam. By this sort of approach, it is frequently possible to reduce the total Y's, or partial qualities, involved in the expression for the overall quality of the gadget, to a relatively small number,—perhaps only two or three.

We have thus reduced our expression for Q, to an unknown function F, of a relatively small number of Y's.

Now while we can't determine the exact form of this function F, it will be pretty evident to us whether an increase or a decrease in the value of any one of these remaining Y's, will improve or injure the overall quality Q; and we won't have to give very much study to the problem to determine how large a change in each partial quality, Y, will produce a noticeable change in the overall quality, Q.

In other words, by selecting or securing actual or experimental data where relatively small changes are involved, we will ordinarily be able to gain at least some idea of the value, within the region of these small changes, of the partial derivative of Q with respect to each of these remaining Y's. In some cases, we may even be able to gain a rough idea of the form of these partial functions.

By considerations of this kind then, we have been able to narrow our problem down to the relatively small number of partial qualities, Y_1, Y_2, Y_3, etc., which have significant bearing on the overall quality Q, and we can generally get some picture of the relative importance of the contribution of each of these partial qualities to the overall quality. We can then confine our attention to this relatively small number of partial qualities which we consider of most importance.

Fortunately, we find that our problem now practically repeats itself.

Each of these partial qualities turns out to be a function of a number of parameters, many of which are purely physical characteristics of the material, or article, or gadget with the quality of which we are concerned. And when I say physical characteristics, I include mass, dimensional, chemical, electrical, magnetic, ionic, nuclear, and any other such characteristics which the thing may have.

That is, we may write:

$Y_i = F_i(X_1, X_2, \text{----}, X_k, \text{----}, X_n)$

where Y_i is any one of the partial qualities which we have found to have significant bearing on the overall quality Q, and where the X's are the several physical characteristics or other parameters involved.

For example, suppose we consider as the partial quality Y_i, the gasoline

*Shewhart Medalist Address, Sixth National Convention, ASQC, Syracuse, N.Y., May 22, 1952.

consumption of the automobile I mentioned earlier, in gallons per mile. Here, representative X parameters might be, for example:

the weight of the automobile;
the heat efficiency of the engine;
the diameter of the wheels;
the size of the tires;
the air-pressure in the tires;
and so on.

Here again, it turns out that we cannot ordinarily determine the exact form of this function F_i. But we can ordinarily gain a somewhat better idea of the partial derivatives of Y_i with respect to each of the X's, and we can frequently determine the complete forms of some of the corresponding partial functions.

Within a region of relatively small change in Y_i, say between Y_i and Y_i', we can of course write:

$$Y_i' - Y_i = \frac{\partial Y_i}{\partial X_1} \cdot dX_1 + \frac{\partial Y_i}{\partial X_2} \cdot dX_2 + \cdots + \frac{\partial Y_i}{\partial X_n} \cdot dX_n .$$

To the extent that these several differential coefficients can be approximated, we can get an idea as to the effect on the partial quality Y_i of changes in the corresponding physical characteristics or other parameters of the gadget. We can thus weed out those X's which have little or no effect on Y_i, and can again concentrate our attention on those which help us to secure an optimum value of the partial quality Y_i.

Not infrequently, the same parameter X_k will be found of significant importance with respect to more than one partial quality Y. In this event, it is necessary to attempt to evaluate the effect of changes in X_k on the overall quality Q.

Again, not infrequently, the solution to the problem may not have been narrowed to the point of merely determining an optimum value of Y_i within a relatively restricted region; or the number of X-parameters requiring consideration may remain substantial. To the extent that Y_i and the X's can be expressed in quantitative terms, so that actual or experimental evaluations of them can be obtained under various conditions, analysis of variance and the power of modern computing machinery are then at our disposal.

When applying this sort of an approach, especially with articles which have been in production for some time, the quality control man will frequently find himself stymied by some detail of the design or by the form of the specification requirements. In this event, he can only refer the problem, with his recommendations, to the development engineer for a restudy of the design and for such changes as necessary in the specifications. Once those changes are made, the quality man is again in a position to proceed.

Out of this sort of consideration, the quality man can ultimately arrive at some optimum value, or level, at which each important characteristic or other parameter, X, of his gadget should be controlled, and he can then proceed, with conventional control chart or other aids, to secure such control.

Now what I have just described to you is the meat of the procedure which has been followed by Bell Laboratories and the Western Electric Company for nearly thirty years in controlling the quality of apparatus and equipment for the Bell Telephone System.

Even though quality people frequently take the initiative in connection with the operation of this procedure in the Bell System, it is not the exclusive responsibility of any one part of the organization. The procedure has been successful because it has represented the cooperative effort of the development, design, enginering, production, inspection, and quality assurance groups, and because it has had the personal interest, and has received the enthusiastic effort and support of the people in all of those groups.

This does not mean that any appreciable number of those people have written down such functional equations as I have mentioned here tonight. But many of them, without knowing it, have become much more expert than they realize in estimating some sorts of partial derivatives and differential coefficients, and in using those estimates effectively for the better control of quality at optimum levels.

While I have been talking about the quality control of gadgets, I might point out that the principles involved are equally applicable to the control of methods and procedures, and even of organizations. In the Bell System, these principles have been applied to such widely differing problems as methods of conducting experimental surveys, methods of modulating carrier waves, systems for switching telephone calls, procedures for rendering telephone bills, procedures for interviewing applicants for employment, and so on.

There is one rather striking coincidence which I should perhaps mention in connection with all of this. The "partial qualities" (Y's), to which I have referred throughout my discussion, are the counterparts of the "yields," and the physical characteristics (X's), are the counterparts of the "operational parameters," of the new science of "Operations Analysis," which proved so helpful to both the British and the American armed forces during World War II.

Aside from these and a few other slight differences in nomenclature, I have so far found little in the way of difference between the philosophies and procedures of "Quality Control" and those of "Operations Analysis." Perhaps this is just another one of those instances which lend support to the old saw that there is little really new in the world.

Back in the early history of this Society, I was persuaded to get out the crystal ball and deliver an address on "The Future of Quality Control." The six years that have elapsed since that time, have indicated that the crystal ball was working pretty well that evening.

But please don't ask me to tempt fate again, and to predict whether we shall still be known as "Quality Controllers" six years hence, or whether we shall then have become "Operations Analysts." I *do* have the fervent hope that we shall *not* have become "Operations *Researchers*." Along with a good many other people, I have a strong preference for reserving the word "research" for investigations having as their objective the discovery of fundamental principles of *general* application.

After all though, shouldn't your Senior Past President be allowed to remain neutral on such questions as this? Perhaps I can have recourse, at this point, to the story about the man on his death-bed who was asked by the clergyman "Do you renounce the devil and all his works?" The man replied "Hold on here! This is no time for me to be making enemies anywhere."

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1000 PER HOUR

1"
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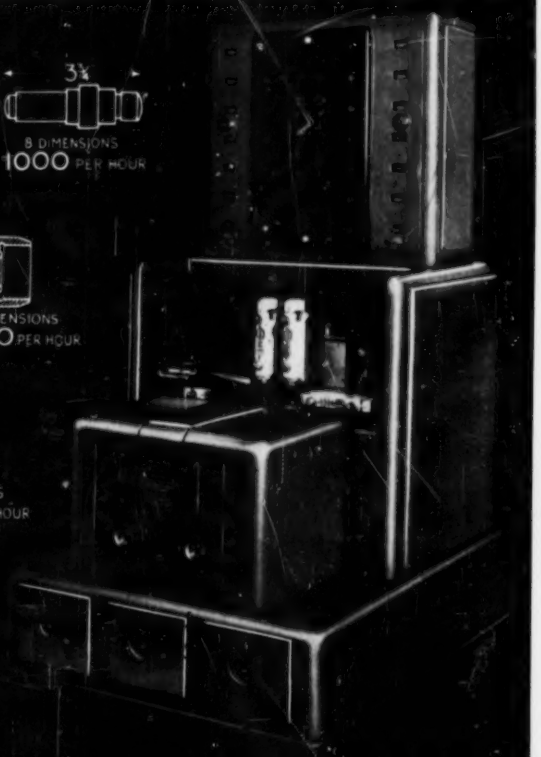
2000 PER HOUR

½"
5 DIMENSIONS
3600 PER HOUR

¾"
1 DIMENSION
10000 PER HOUR



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An Application of Statistical Quality Control Techniques to Specification Requirements*

C. L. MATZ

Engineer, Material Specification Coordination, Commonwealth Edison Company

IT is the purpose of this paper to illustrate how advantage can be taken of available data by applying statistical methods to establish realistic specifications and to trace causes of significantly large variations in the data.

As an illustration, we will consider a synthetic liquid known by the generic name of "askarel." It is used in electrical equipment as a cooling and insulating medium. It has an advantage over the petroleum base insulating liquids in that it eliminates fire hazards. Its stability in service and its aging characteristics are, therefore, of great interest to utility engineers.

One of the most important properties that this liquid must possess is dielectric strength, which is a measure of its ability to withstand high voltage. It is important that the liquid retain this characteristic over long periods. To study these properties, tests were made on several hundred transformers ranging in service from 6 months to 10 years. Each transformer was tested at approximate intervals of from 6 to 12 months and test results were available for each month of the year. For comparison, the dielectric strength was also determined on the liquid from new transformers. The transformers from which samples were taken have insulating liquid in two compartments: the main body of the transformer which houses the core and coils, and the switch compartment which houses the equipment for the electrical connections. Both are filled with askarel and are hermetically sealed by the manufacturer. When the transformers are installed in service, the purchaser has to remove the liquid from the switch compartments in order to make the electrical connections. They are then refilled and resealed. (See Figure 1)

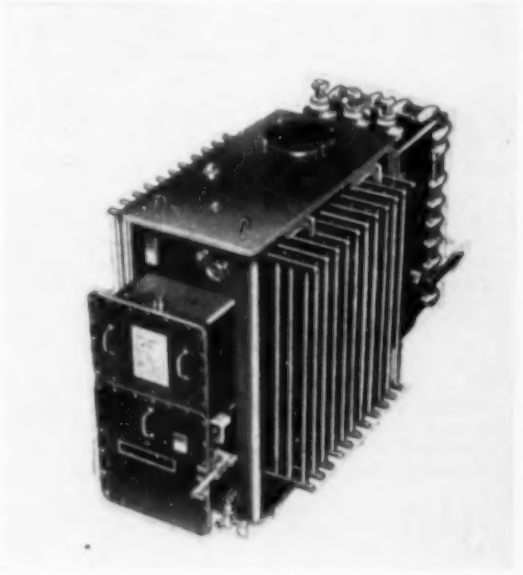

Figure 1—**Typical Transformer with Switch Compartment**

PROBLEMS TO BE SOLVED

One of the immediate problems was to determine a lower specification limit for dielectric strength of the liquid. To determine this limit, 254 tests were made on samples taken from 127 new transformers received over a period of about a year. One sample was taken from the main body of the transformer and one from the switch compartment. An examination of the data indicated wide variations in dielectric strength values. Moreover, the average values of dielectric strength of samples taken from the switch compartments were noticeably lower than those taken from the transformer, so that agreement on a minimum value of dielectric strength was difficult to reach by generally accepted methods of handling such data. After discussions between the utility and manufacturers' engineers, the author was requested to make a statistical analysis of the data in an attempt to suggest a limit that would be satisfactory in service and within the capability of the processes of the three suppliers.

From an operational point of view, the value of the minimum limit would be affected by the aging properties of the liquid. Experience in this respect was limited, and the test values of dielectric strength varied so widely from test to test, even on samples taken from the same transformers within relatively short periods, that no conclusions could be drawn from the test data without the aid of statistical analysis.

It is generally agreed that when the dielectric strength of the insulating liquid falls below a 20 kv breakdown value, the liquid is not safe for use. It is obvious, therefore, that if the liquid ages rapidly, economic considerations would demand a rather high initial value of dielectric strength. In addition, the very large range in test values from tests made periodically on samples taken from the same transformers caused some apprehension. The problem was, therefore, resolved into three parts:

(1) To set a minimum value of dielectric strength for the specification that would be within the manu-

*Paper presented before the Chicago Section, ASQC, April, 1950.

TABLE 1—**Data and Computations for an Attributes Test of Significance**

Size (KVA)	Supplier A			Supplier B			Supplier C			Total		
	N	x	p	N	x	p	N	x	p	N	x	p
500	15	8	.53	26	8	.31	26[a]	0	.00	67	16	.24
750	18	9	.50	11[a]	3	.27	20[b]	7	.35	49	19	.39
1000	3	0	.00	3	0	.00	0	0	..	6	0	.00
Total	36	17	.47	40	11	.28	46	7	.15	122	35	.29

(a) excluding one tie
(b) excluding two ties

N = number of tests
x = number of times D > T

p = x/N

facturers' process capabilities.

(2) To determine the rate of deterioration of the dielectric strength in service.

(3) To trace, if possible, the causes of the wide variations in test values.

To study the aging characteristics, over 1630 dielectric strength tests were made on askarel taken from both transformers and switch compartments in service from 6 months to 10 years. These values, together with the 254 tests on new askarel, provided the data for solving the problem.

HOMOGENEITY OF THE DATA

An inspection of the data from tests on new askarel indicated a difference between the values of dielectric strength of samples taken from the transformers and those taken from the disconnect switch compartments. Hereafter these values will be referred to as T and D values.

A test of significance by attributes was applied to the data from Manufacturers A, B, and C, as shown by the data in Table 1.

If there were no significant difference between dielectric strength values, D could be expected to exceed T as many times as T exceeds D.

If

x_e = the expected number of times D should exceed T, and

x_o = the observed number of times D exceeds T,

then

$$t = \frac{|x_e - x_o| - \frac{1}{2}*}{(Npq)^{\frac{1}{2}}}$$

has an approximately normal distribution.

Substituting the values given in Table 1 in the formula for t yields the following ratios:

Supplier A:

$$\frac{|18 - 17| - \frac{1}{2}}{[(36)(.5)(.5)]^{\frac{1}{2}}} = \frac{.5}{3} = .1667.$$

Prob. ($t \geq .1667$) = .868.

Supplier B:

$$\frac{|20 - 11| - \frac{1}{2}}{[(40)(.5)(.5)]^{\frac{1}{2}}} = \frac{8.5}{3.16} = 2.6889.$$

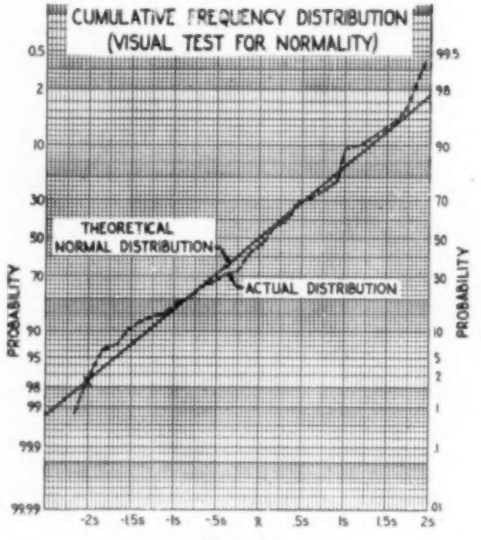

Figure 2

Prob. ($t \geq 2.6889$) = .0072.

Supplier C:

$$\frac{|23 - 7| - \frac{1}{2}}{[(46)(.5)(.5)]^{\frac{1}{2}}} = \frac{15.5}{3.39} = 4.5723.$$

Prob. ($t \geq 4.5723$) = .00002.

These calculations show that, with the exception of Manufacturer A, the D values are significantly lower than the T values. As stated above, the reason for this difference is the fact that the liquid from the disconnect compartments has to be rehandled in the process of installation and is exposed to air and absorption of moisture which would tend to lower dielectric strength. This situation has been corrected by handling the liquid from the disconnect compartment under nitrogen gas pressure. Manufacturer A placed a porous moisture

* ($\frac{1}{2}$ is subtracted to make possible the use of a table of the normal distribution.)

TABLE 2—**Computation of Cumulative Frequency Distribution for Askarel Samples Taken from Switch Compartments**

x	f	cum. f	$x - \bar{x}$	$\frac{x - \bar{x}}{s}$	Mid-point	% Below
20	1	1	−16.3	−2.312		
21	0	1	−15.3	−2.170	−2.17	.78
22	3	4	−14.3	−2.028	−1.96	3.1
23	4	8	−13.3	−1.887	−1.82	6.3
24	1	9	−12.3	−1.745		
					−1.67	7.1
25	4	13	−11.3	−1.603	−1.53	10.2
26	3	16	−10.3	−1.461	−1.39	12.6
27	1	17	− 9.3	−1.319	−1.25	13.4
28	2	19	− 8.3	−1.177	−1.11	15.0
29	5	24	− 7.3	−1.035		
					− .96	18.9
30	2	26	− 6.3	− .894	− .82	20.5
31	6	32	− 5.3	− .752	− .68	25.2
32	3	35	− 4.3	− .610	− .54	27.6
33	4	39	− 3.3	− .468	− .40	30.7
34	2	41	− 2.3	− .326		
					− .26	32.3
35	13	54	− 1.3	− .184	− .11	42.5
36	5	59	− .3	− .043	.07	46.5
37	10	69	.7	.099	.17	54.3
38	5	74	1.7	.241	.31	58.3
39	12	86	2.7	.383		
					.45	67.7
40	3	89	3.7	.525	.60	70.1
41	5	94	4.7	.667	.74	74.0
42	5	99	5.7	.809	.88	78.0
43	13	112	6.7	.950	1.02	88.2
44	2	114	7.7	1.092		
					1.16	89.8
45	2	116	8.7	1.234	1.30	91.3
46	1	117	9.7	1.376	1.45	92.1
47	3	120	10.7	1.518	1.60	94.5
48	3	123	11.7	1.660	1.73	96.8
49	3	126	12.7	1.801		
50	0	126	13.7	1.943	1.94	99.2
51	1	127	14.7	2.085		

x = Test kv $\bar{x}$ = 36.3 s = 7.05

absorbent in the disconnect compartments which evidently removed the moisture picked up during the handling operations.

An analysis of variance (details omitted in this paper) further confirmed that the differences among the various sample groups taken from the transformer and switch compartment of the three manufacturers were significant.

To test the normality of the distribution, cumulative frequency distributions of dielectric strength were calculated and plotted on probability paper. A typical distribution is shown in Table 2 and Figure 2. Our primary interest is in the fluctuations at the tails of the distribution. It will be noted that at the 5% and 95% probabilities the tails of the distribution bend downward and upward. Our interest is, of course, centered in the lower tail only. Limits calculated on the assumption of a normal distribution would be conservative as the actual values are not quite as low as they would be if the distribution were exactly normal, i. e., the distribution is slightly truncated.

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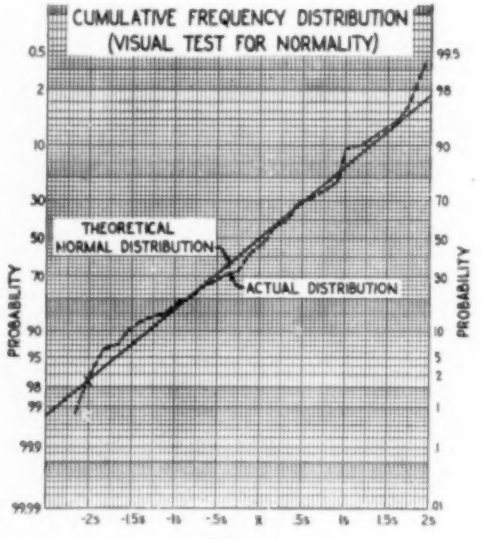

Figure 2

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x = Test kv $\bar{x}$ = 36.3 s = 7.05

absorbent in the disconnect compartments which evidently removed the moisture picked up during the handling operations.

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COMPUTATION OF LOWER LIMIT FOR NEW ASKAREL

The lower limit we choose will depend on the assurance we require that not more than a stated proportion will be below this limit. We call this assurance

a "confidence level", and the proportion below our limit a "fraction defective." If we agree that a confidence level of 0.95 and a fraction defective of 0.01 is acceptable, then, on the basis of the assumption of normality, we may compute a lower value of dielectric strength such that we can be 95 percent confident that 99 percent of the samples tested will lie above this limit.

Let

M = Lower limit;

p = Proportion above the calculated limit;

$1 - p = p_1$ = Fraction defective;

γ = Confidence level;

$\alpha = 1 - \gamma$ = risk that observations will fall below the lower limit M;

K_1 = A normal deviate exceeded with probability p_1*;

K_α = A normal deviate exceeded with probability α;

s = Standard deviation of the sample;

N = Sample size.

For a fraction defective $p_1 = 0.01$, we find from a normal table that $K_1 = 2.326$. For a confidence level of $\gamma = 0.95$, $\alpha = 1 - 0.95 = 0.05$, and from a normal table we find $K_\alpha = 1.645$. M may be computed from the equation

$$M = \bar{x} - ks.$$

The constant k is calculated from the equation

$$k = \frac{K_1 + \sqrt{K_1^2 - ab}}{a}$$

where

$$a = 1 - \frac{K_\alpha^2}{2(N-1)} = 1 - \frac{(1.645)^2}{2(127-1)} = 0.985,$$

$$b = K_1^2 - \frac{K_\alpha^2}{N} = (2.326)^2 - \frac{(1.645)^2}{127} = 5.382,$$

$$k = \frac{2.326 + \sqrt{[(2.326)^2 - (0.985)(5.382)]}}{0.985} = 2.699.$$

In this example, $\bar{x} = 36.3$ kilovolts and $s = 7.05$ kilovolts. The value of M is therefore:

$$M = 36.3 - (2.699)(7.05) = 17.27 \text{ kilovolts.}$$

The above calculations are for samples taken from the disconnect switches, and the calculated value is obviously too low, being less than 20 kv. Similar calculations for the samples taken from the transformers are shown in Table 3. For the same confidence level and fraction defective, the M value is 26.2 kv.

Since the cause for the significant difference between T and D is known, and can be eliminated, a value of 26 kv would represent a practical minimum limit which the manufacturers' processes should be able to meet. It may be mentioned that an analysis like the above, applied to the data of each of the three suppliers separately, gave minimum limits in each case that varied only a fraction of a kv from 26.

*K_1 = a value of $\frac{x - \bar{x}}{s}$ in a normal table such that the one-tail area beyond this point is p_1.

TABLE 3 — **Lower Tolerance Limits M in Kilovolts**

LOCATION					
Transformer (T)			Switch Compartment (D)		
γ	p	M	γ	p	M
.95	.05	29.5	.95	.05	23.3
.95	.01	26.2	.95	.01	17.3

DETERMINATION OF AGING

The second phase of the problem was to determine the rate of deterioration of dielectric strength over the period of 10 years that the transformers were in service. From the 1624 tests made on transformers in service from 6 to 120 months, a correlation analysis was made with the dielectric strength as the dependent variable, Y, and time in months as the independent variable, X.

The scatter diagrams indicated a linear relationship in each case. The regression equations were:

For askarel from switch compartments:

$Y = 39.0 + 0.01X$;

$r = 0.049$; $S_Y = 6.1$ kv; $N = 1624$.

For askarel from transformers:

$Y = 39.0 + 0.013X$;

$r = 0.078$; $S_Y = 5.3$ kv; $N = 1626$.

Although the coefficients of correlation are very small, nevertheless the null hypothesis of no relationship is rejected at the one percent level for askarel taken from the top of transformers, and is rejected at the five percent level for askarel taken from the switch compartments*. Thus there appears to be a bona fide positive relationship between dielectric strength and time, which indicates a slight improvement of dielectric strength in service. It is not apparent why this improvement takes place. A possible explanation is that residual amounts of contamination, such as moisture, that would tend to lower the dielectric strength have gradually been eliminated from the askarel, possibly by absorption in the insulation.

There was still the problem of explaining the large fluctuations in the periodic tests on samples taken from the same transformer. For example: In one instance, in the month of February, the dielectric strength of the askarel from a transformer tested 45 kv. In May of the same year it dropped to 19 kv, and in August, three years later, the same liquid tested 51 kv. These large swings left the operating people in a quandary as to what to do when the dielectric strength is reduced below the danger line of 20 kv. If action had been taken on the basis of the May test results, a substantial sum of money would have been wasted.

*For samples of the size used here and the null hypothesis that the universe sampled is uncorrelated, the test criterion is given by $t = r\sqrt{N-1}$, and reference is to a normal table.

For askarel from transformers, we find $t = 3.14$.

For askarel from switch compartments, we find $t = 1.975$.

STUDY OF CAUSES OF VARIATION

The data of 1959 tests* made on the liquid from transformers in service from the time of installation up to 120 months were separated into 12 groups, according to the months in which the tests were made, and the standard deviation for each month was determined. The values were as shown in Table 4.

TABLE 4—**Standard Deviations in Kilovolts by Months For Askarel in Service**

Month	Std. Dev.	Month	Std. Dev.
Jan.	4.54	July	5.08
Feb.	4.47	Aug.	6.97
March	5.10	Sept.	6.14
April	4.68	Oct.	5.75
May	5.64	Nov.	4.68
June	5.87	Dec.	4.97

The standard deviations for dielectric strengths of new askarel from the three suppliers were as shown in Table 5.

TABLE 5—**Standard Deviations in Kilovolts New Askarel**

Vendor	Transf.	Switch Comp.
A	5.11	6.37
B	5.32	6.88
C	5.80	7.38

*An additional 333 tests were added by using the data of tests made on transformers in service the first 6 months after installation.

The variance of all the 1959 tests of the askarel taken from the transformers in service was 28.2263 and the variance of the 127 tests of askarel taken from the top of new transformers received from the three suppliers was 32.6158.

An unbiased estimate of the universe variance for new askarel $\hat{\sigma}_1^2$ is 32.8747 and an unbiased estimate of the universe variance of the askarel in service $\hat{\sigma}_2^2$ is 28.2407. Hence

$$F = \frac{\hat{\sigma}_1^2}{\hat{\sigma}_2^2} = \frac{32.8747}{28.2407} = 1.16.$$

With 126 and 1958 d. f. the $F_{.05}$ ratio is approximately 1.22. Thus the F test lends support to the belief that variation in dielectric strength is the same for askarel which has been in service as that for new askarel.

Are the variances for the 12 months mutually consistent? To answer this question, Bartlett's test* was applied as a criterion for testing the homogeneity of a set of variance estimates.

Let

n_i = number of tests made in the same month of each year;

S_i = standard deviation for the same month of each year;

σ = standard deviation of all the tests for the period being studied;

$$\sigma^2 = \frac{\Sigma\, n_i S_i}{N} \quad \text{where } N = \Sigma\, n_i.$$

Let

B = the significance ratio.

*See Ref. 1, pp. 387-388.

TABLE 6—**Values for Comparing Variances**

Month	No. of Tests (n_i)	Variance (S_i^2)	$n_i S_i^2$	$\log_{10} S_i^2$	$n_i \log_{10} S_i^2$	$\frac{1}{n_i}$
Jan.	227	20.60	4676.20	1.311754	297.768158	0.004405
Feb.	162	20.00	3240.00	1.301030	210.766860	0.006173
Mar.	336	26.11	8772.96	1.416807	476.047152	0.002976
April	270	21.94	5923.80	1.341237	362.133990	0.003704
May	228	31.81	7252.68	1.502564	342.584592	0.004386
June	112	34.44	3857.28	1.539578	172.432736	0.008929
July	72	25.82	1859.04	1.411956	101.660832	0.013889
Aug.	167	48.52	8102.84	1.685921	281.548807	0.005989
Sept.	74	37.75	2793.50	1.576917	116.691858	0.013514
Oct.	64	33.14	2120.96	1.520353	97.302592	0.015625
Nov.	57	21.84	1244.88	1.339253	76.337421	0.017544
Dec.	190	24.82	4715.80	1.384802	263.112380	0.005263
Totals	1959	—	54559.94	—	2798.387378	0.102397

Then

$$B = \frac{1}{C}(N\log_e\sigma^2 - \Sigma n_i \log_e S_i^2)$$

$$= \frac{2.30259}{C}(N\log_{10}\sigma^2 - \Sigma n_i \log_{10} S_i^2)$$

$$C = 1 + \frac{\Sigma\,(1/n_i) - \dfrac{1}{N}}{3(k-1)},$$

where

k = number of groups, in this case, number of months.

Table 6 gives the values needed in the above equations. Substituting, we have:

$$\sigma^2 = \frac{54559.94}{1959} = 27.85;\ \log_{10} 27.85 = 1.444825.$$

$$\Sigma(1/n_i) = 0.102397;\ \frac{1}{N} = \frac{1}{1959} = 0.000510$$

$$C = 1 + \frac{(0.102397 - 0.000510)}{(3)(11)} = 1 + \frac{0.101887}{33}$$

$$= 1 + 0.003087.$$

$$B = \frac{2.30259}{1.003087}[(1959)(1.444825) - (2798.387378)]$$

$$= 2.2955\ (2839.041218 - 2798.387378)$$

$$= (2.2955)(40.653) = 93.3.$$

The statistic B has approximately the chi square (χ^2) distribution. Since we are analyzing data over 12 months, or 12 groups, there are 11 degrees of freedom. A χ^2 table shows that for 11 degrees of freedom, the .001 value is only 31.3. Hence, B = 93.3 is highly significant, and we reject the hypothesis that these 12 monthly variances are homogeneous.

If we group the standard deviations of the months requiring heat in the laboratory into one group and the standard deviations of the months that do not require heat into another group, it will be noted that standard deviations for the months requiring heat in the laboratory are generally smaller than those of the unheated months. (See Table 7)

TABLE 7—Standard Deviations in Kilovolts by Months Classified on Basis of Heat Requirements in Laboratory

Heat Required In Buildings		Heat Not Generally Required In Buildings	
Month	Std. Dev.	Month	Std. Dev.
Jan.	4.54	May	5.64
Feb.	4.47	June	5.87
March	5.10	July	5.08
April	4.68	Aug.	6.97
Nov.	4.68	Sept.	6.14
Dec.	4.97	Oct.	5.75

Are these two groups mutually consistent with respect to variability? Bartlett's test is again applicable; this time with k = 2 instead of 12. Table 8 gives the required data and calculations.

For 1 degree of freedom, a χ^2 table shows 10.8 as the .001 value. Hence, B = 46.9 is highly significant. We can conclude, therefore, that the condition of the atmosphere under which the samples are handled influences the values of dielectric strength obtained in the tests.

A question of interest is whether the variance is homogeneous within the months requiring heat in buildings, and likewise within the months not requiring heat. Tables 9 and 10 indicate the answer.

These values of B (12.1 and 13.2) are not significant at the 1 percent level in either case.

All of these investigations thus lead to the conclusion that the apparent instability is not attributable to the askarel when handled properly, but to the atmospheric conditions during the tests surrounding the samples. This conclusion also seems to be confirmed in operating practice. As a result of the analysis, consideration is being given to changes in the method of sampling, and also to the method of handling the samples in the laboratory.

SUMMARY OF THE ANALYSIS

(a) The "range" of dielectric strength values of askarel in service is about the same as that of new askarel.

(b) The dielectric strength values of askarel taken from switch compartments are significantly lower than the values of dielectric strength of askarel taken from transformers. The only plausible explanation for this condition is contamination in handling. Measures have been taken to remove these assignable causes.

(c) For an acceptance level of 0.01 defective and a confidence level of 0.95, the lower limit is 26 kv for askarel taken from transformers and 17 kv taken from disconnect switches. Since the assignable causes for low dielectric strength of the askarel from the switch compartments is known and can be eliminated, it need not be considered in the specification.

(d) There is no reduction in dielectric strength of the askarel after 10 years in service; in fact there is evidence of slight improvement.

(e) An analysis of the variance in dielectric strength of all the samples taken from 400 transformers in service over a period from time of installation up to 10 years, aggregating 1,959 tests, justifies the conclusion that the variations are assignable cause variations. The probability that such wide variations could be chance variations is practically zero.

(f) The analysis points to atmospheric condition as being the cause of the variations. Since the transformers in service are hermetically sealed and are not subject to the influence of changing atmospheric conditions, the variations must be attributed to changes that take place in the sample.

Our objective has been to demonstrate the effectiveness of statistical quality control techniques as an engineering aid in setting specification requirements, and in helping to answer some of the perplexing questions that often arise. We have merely sought to attract the interest of those who are at the administrative level of business, as well as of engineers who are engaged in specification work, and to direct their attention to the fact that there are useful tools that can materially assist in the solution of such problems without relying entirely on experience and intuition.

TABLE 8

Grouping	n_i	S_i^2	$n_i S_i^2$	$\log_{10} S_i^2$	$n_i \log_{10} S_i^2$	$\frac{1}{n_i}$
Months Requiring Heat	1242	23.19	28801.98	1.365301	1695.703842	0.000805
Months Not Requiring Heat	717	36.27	26005.59	1.559548	1118.195916	0.001395
Totals	1959	—	54807.57	—	2813.899758	0.00220

$$\sigma^2 = \frac{54807.57}{1959} = 27.977; \quad \Sigma(1/n_i) = 0.00220; \qquad C = 1 + \frac{0.00220 - 0.00051}{3(2-1)} = 1.00169.$$

$$\frac{1}{N} = \frac{1}{1959} = 0.00051; \qquad \log_{10} 27.977 = 1.446801; \qquad B = \frac{2.30259}{1.00169}[(1959)(1.446801) - 2813.899758] = 46.9.$$

TABLE 9—**Significance Test of Variance for Months Requiring Heat**

Month	n_i	S_i^2	$\log_{10} S_i^2$	$n_i \log_{10} S_i^2$	$n_i S_i^2$	$\frac{1}{n_i}$
Nov.	57	21.84	1.339253	76.337421	1244.88	0.017544
Dec.	190	24.82	1.384802	263.112380	4715.80	0.005263
Jan.	227	20.60	1.311754	297.768158	4676.20	0.004405
Feb.	162	20.0	1.301030	210.766860	3240.00	0.006173
Mar.	336	26.11	1.416807	476.047152	8769.60	0.002976
April	270	21.94	1.341237	362.133990	5923.80	0.003704
Totals	1242	—		1686.165961	28570.28	0.040065

$$\frac{1}{N} = \frac{1}{1242} = 0.000805; \quad \Sigma(1/n_i) - 1/N = 0.040065 - 0.000805 = 0.039260; \qquad C = 1 + \frac{0.039160}{3(6-1)} = 1.00262.$$

$$\sigma^2 = \frac{28570.28}{1242} = 23.0055; \quad \log_{10} 23.0055 = 1.361822; \qquad B = \frac{2.30259}{1.00262}[(1242)(1.361822) - 1686.165961] = 12.1.$$

TABLE 10—**Significance Test of Variance for Months Not Requiring Heat**

Month	n_i	S_i^2	$\log_{10} S_i^2$	$n_i \log_{10} S_i^2$	$n_i S_i^2$	$\frac{1}{n_i}$
May	228	31.81	1.502564	342.584592	7252.68	0.004386
June	112	34.44	1.539578	172.432736	3857.28	0.008929
July	72	25.82	1.411956	101.660832	1859.04	0.013889
Aug.	167	48.52	1.685921	281.548807	8102.84	0.005989
Sept.	74	37.75	1.576917	116.691858	2793.50	0.013514
Oct.	64	33.14	1.520353	97.302592	2120.96	0.015625
Totals	717	—	—	1112.221417	25986.30	0.062332

$$\frac{1}{N} = \frac{1}{717} = 0.013947; \quad \Sigma(1/n_i) - 1/N = 0.062332 - 0.013947 = 0.048385; \qquad C = 1 + \frac{0.048385}{3(6-1)} = 1.00323.$$

$$\sigma^2 = \frac{25986.30}{717} = 36.243; \qquad \log_{10} 36.243 = 1.559224; \qquad B = \frac{2.30259}{1.00323}[(717)(1.559224) - 1112.221417] = 13.2.$$

References

1. *Techniques of Statistical Analysis* by Eisenhart, Hasty and Wallis.—McGraw Hill Book Co., N.Y.
2. *Statistical Tables* by Fisher & Yates, Oliver & Boyd, London.

Acknowledgement

Appreciation is expressed to W. Allen Wallis of the University of Chicago & R. V. Panfil of the Illinois Bell Telephone Company for their valuable suggestions.

REPORT OF THE
Sixth National Convention
American Society for Quality Control

Syracuse, New York, May 22-24, 1952

RAIN! RAIN! RAIN! For three days, May 22-24, the Syracuse Weather Bureau forecast read "showers". This was almost prearranged. Local official forecasts have a consistent record of 30% accuracy. Therefore, the Convention Committee felt that the best weather insurance possible would be a daily "rain" check. When approached, the Weatherman stated, "Why, that's what the weather will be, anyway", and the committee departed, rejoicing.

As the 1,972 pleased delegates to the Sixth Annual Convention well know, the laws of probability operated in the best possible way—two and one-half more beautiful days could not have been ordered—thus providing a perfect setting for a perfect convention. The weatherman got in his licks Saturday afternoon, thus keeping his average intact, but nobody minded. In addition to the registered delegates, visitors spent some time in the exhibits area as invited guests of our many exhibitors. Every one appeared to enjoy his experiences, and many appreciative comments were heard.

On Monday, May 19, the early birds started to arrive; by Wednesday enough delegates had reached the hotels to create a serious housing problem. This was ironed out, but housing remained the greatest difficulty of the Convention, as had been anticipated. However, no one had to stand in a corner to sleep, and practically everyone bore the strain with good humor and understanding.

Wednesday night, a wager was made that the following morning's registration would take 45 minutes of each person's time. The other side insisted that five minutes would be a maximum. When the payoff occurred, the loser admitted his time was "just under one minute", after entering the convention building. This very pleasant start of the official activities of the Convention was due to the painstaking preparations of the Registrar and his aides. The registration procedure was designed to expedite movement of the registrants into the more enjoyable parts of the day's activities, and was extremely successful.

THURSDAY

By opening time, all the Exhibits were organized and the red-ribboned Exhibitors wore their brightest smiles. Although the Gauge and Inspection Equipment manufacturers predominated, there were several displays devoted to telling the quality control story of that particular company. Among these were Carrier Corporation, Oberdorfer Foundries, General Electric Company, and Sylvania Electric Company, all from the Syracuse area; and International Harvester and Ford Motor Company from further away. A complete list of exhibitors is given elsewhere in this report.

The official welcoming of the delegates occurred at the opening Assembly, when Mr. Leon Bass, the general Chairman, declared the Convention open and introduced the Honorable Thomas J. Corcoran, Mayor of Syracuse. Mr. Corcoran expressed the city's delight at being able to serve this convention, and invited everyone to make himself "at home" in Syracuse. Mr. John T. Schenck, president of Engelberg Huller Company and chairman of the board of directors of the Syracuse Manufactureers' Association, then introduced the principal speaker of the day, Mr. Francis K. McCune, assistant manager of General Electrict Company's Engineer Service Division at Schenectady, who stressed the role of quality control methods in obtaining the "best values" of any process or activity, concluding that "quality control means more goods for more people at less cost", which shows it as a valuable extension to all production operations and studies.

Luncheon for 1,250 people is not the project most hostesses would choose for their next social activity. However, this did not appear to cause any concern to the officials of the two Syracuse hotels who combined forces for the catering operation. The use of pallets, lift trucks, and panel trucks for transporting the food from the hotels and returning the dishes thereto, put the operation into a familiar industrial pattern, and the hordes of efficient waitresses made the service rapid and pleasant. Announcements at the luncheon were followed by the committee's surprise, a quality control quiz for the delegates. This was a series of multiple choice questions on SQC subjects, tending to prove that "People are Normal".

The first technical sessions took place as scheduled, with all meetings being held in the Auditorium except the largest of all, the panel made up of Dr. Juran, Ernest Robinson, Hugh Smallwood, and Raymond Saddoris. This one, attended by approximately 800 intrigued delegates, filled the ballroom of the Hotel Syracuse.

At the same time, the educational series, with some 90 trainees, started its three day stint on the curtained-off stage of the main auditorium, under the expert direction of Messrs. Bender, McDermott, and Oakley. The training manual became so popular with those who were not attending this particular series, that the authors were hard put to retain enough for the class; even the Publicity Chairman lost the one he had filched—on the very last day of the convention some visitor managed to make off with it!

At 4:05 PM, the annual meeting of the American Society for Quality Control convened in the meeting room on the top floor of the Auditorium. Reports of the various committees had been received in advance by the President, who read a consolidated report for all of them. This indicated a great deal of committee activity during the year, including the formation of definite divisions in particular fields which

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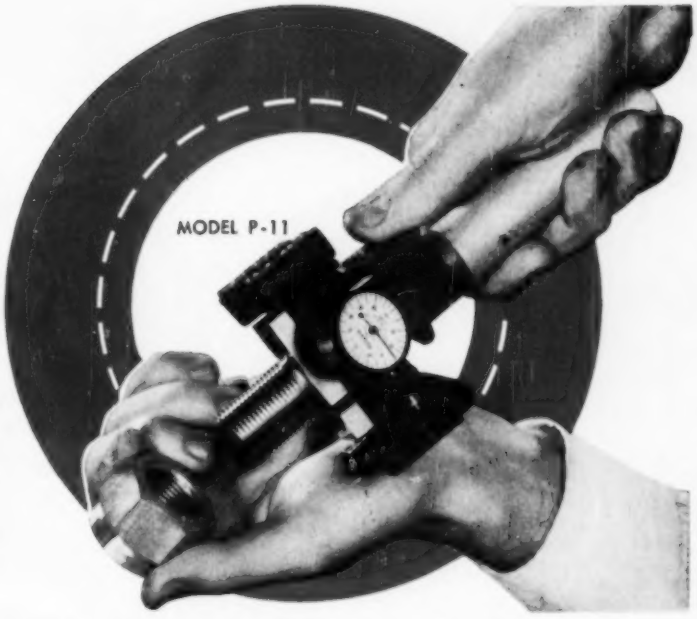

The P-11 is a portable comparator gage. Variation from basic size of pitch diameter, form and lead are shown in a single reading on the dial indicator accurate to .0005". Interchangeable pairs of segments inspect all classes of threads in a range from 5/16" to 5" diameter.

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This gage is designed for use at the inspection bench or in the shop. It is used for quality control since complete control of the thread cutting process is possible. The indicator reading of variation from basic size tells exactly where within limits the work is running. For this reason also, the gage is used for checking tool wear in production jobs.

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Dorian Shainin receives congratulations of the Society as winner of the 1951 Brumbaugh Award.

George D. Edwards receives congratulations of the Society as the 1951 Shewhart Medalist.

Brig. Gen. Ralph H. Tate, Friday Luncheon Speaker.

have applied for charter to the national organization. The appointment of a full-time managing editor for the Society's publications was announced, and a report of other publications activity was given by the Editor. The meeting adjourned until the Annual Banquet, with the appointment of a teller's committee to count the ballots and report the results of the balloting to the Annual Banquet.

After the afternoon meetings, many of the delegates visited the exhibits and also parties the exhibitors were sponsoring in various locations throughout the city. These gatherings were well attended and enjoyed by all.

The attendance of 975 at the Annual Banquet completely absorbed the attention of the caterers as an excellent meal was provided. Following the meal, the society took up the main business of the meeting, which was the presentation of the Brumbaugh award and the Shewhart Medal, and the installation of the newly elected officers, following certain reports to the organization.

The Brumbaugh award was presented to Dorian Shainin, Chief Inspector, Hamilton Standard Division, United Aircraft Corporation, for his paper printed in the July, 1950, issue of "Industrial Quality Control", entitled "The Hamilton Standard Lot Plot Method of Acceptance Sampling by Variables". The award consists of a check for $50 and a suitably inscribed certificate. Mr. Shainin responded with a short talk, giving much of the credit for the inspiration and development of the lot plot theory to several friends and coworkers.

Wade Weaver, retiring ASQC president, introduced the guests of honor at the speaker's table and reviewed society progress during his administration in the following President's Report:

"My associations with the individuals whom I have just introduced have been very close over the past two years. These individuals—along with the approximately 230 members of the Society's 28 committees and boards—are the ones to whom the Society owes its appreciation and thanks for the many fine accomplishments which have ensued. The routine reports of the Board of Directors, Officers, and Committees were presented to the members of the Society at the Annual Meeting this afternoon, but I believe you will be interested in hearing some of the highlights of the past year's operations.

"The somewhat phenomenal growth characteristics which our Society exhibited during the first five years of its existence—we had our Sixth birthday on February 16 of this year—were continued at an even greater pace. Membership increased from 4,245 as of June 30, 1951 to 6,074 as of Monday of this week, an increase of 43 per cent, the largest gain in our history, both as to members and percentage-wise. This was accompanied by the granting of charters to 11 New Sections of the Society, giving us a total of 59 Sections, of which three are in Canada and one in Mexico. Three of our Sections—Metropolitan New York, Indianapolis, and Chicago—have over 400 members; Cleveland now has over 300. Last year only two of the Sections were over 300.

"Material impetus to this membership increase was provided by the customary series of unusually splendid Conferences which were held throughout the year in various parts of the country. Attendance at practically all of these was at record high levels, with the largest—the Middle Atlantic Conference in New York—drawing a crowd of over 1,300. These affairs have played a magnificent part in the development and strengthening of our Society.

"The increased size of our membership has naturally produced a highly favorable effect upon our financial picture. For the fiscal year 1950-51 the Society operated substantially within its budget, and increased its net worth some 450 percent. This afforded us an opportunity, among other things, to expand our publications activities, and Industrial Quality Control, which had enlarged by 25 percent last year, was again enlarged for 1951-52. The recent issues reflect an expansion during the

ASQC Officers for 1952-53. Left to right: Raymond S. Saddoris, Vice-President; Arthur Bender, Jr., Vice-President; Wade R. Weaver, Junior Past President; Simon Collier, President; Paul A. Robert, Treasurer; Julian H. Toulouse, Vice-President. Not shown: Edward B. Haden, Executive Secretary.

ASQC Book Booth attracts lively interest of delegates.

Mr. Ken-ichi Koyanagi, Managing Director, Japanese Union of Scientists and Engineers, ASQC's guest at Friday Luncheon.

past two years of 63 percent. Concurrent with this, our paid advertising, exclusive of the special May Convention issue, has more than doubled during the past year —a sure sign that the character and value of our publication is receiving increased recognition.

"It is a little early to forecast the accurate financial picture which will obtain at the end of the current fiscal year, but at the three-quarter mark, March 31, we were operating at 73 percent of our budget, and I know of nothing which should materially alter this picture. There is no doubt whatever that we shall further materially improve our financial situation, thus enabling the substantial enlargement of our activities scope—for which plans are already worked out and in process of consummation—as well as placing ourselves in a much stronger position to withstand the adversities which I believe we will agree inevitably lie ahead of us. Consistent with good financial policy, a substantial portion of this surplus has been put to work. An investment program was inaugurated a few months ago and the Society now has a block of diversified income producing securities which further adds to our stability. This entire matter of improved financial soundness has been one of outstanding satisfaction.

"All of this increased activity has imposed new and greater problems upon our headquarters office in New York City. This office has been doubled in size, our own complete addressograph system has been purchased and set up, our technical literature service has been consolidated here, and we are now in a greatly improved position to handle the ever mounting volume of routine Society matters with increased despatch and economy.

"For some time it had become clearly evident to the Officers of the Society that we had completely outgrown the administrative set-up under which the Society operated, as well as certain phases of our Constitution. Recognizing this, the Board of Directors recommended that the number of Vice Presidents be increased to three so that the workload might be more equitably distributed. Also, the Board subsequently approved for submission to the membership for a "vote of intent," a comprehensive plan to completely revise the administrative set-up of the Society so as to make it more compatible with the present size and scope of our Society. The Constitutional reforms which will result from these two actions will very greatly facilitate long range planning, as well as current administration of the rapidly enlarging multitude of problems with which the executives of the Society are confronted. These reforms have been sorely needed, and it is most gratifying that they are approaching factual reality.

"All in all, I believe there is great reason for extreme satisfaction in the progress our Society has made. It will appear obvious to many that there is much that was not done, but first things must come first. Also, it must be remembered that all of the time and effort put forth by our people is on an entirely voluntary basis, and in these highly pressurized times it is not possible for many to devote to Society affairs the amount of time which their normal inclinations would dictate.

"I should like to take this opportunity to express the sincerest appreciation to the Officers and Directors of the Society, and to the Chairman and Members of the Society's many boards and committees for their interest, enthusiasm, and advice, and for their loyalty and hard work during my tenure of office as President. The problems have been many and perplexing, but the spirit with which everyone has pitched in and helped has been most gratifying. I value most highly the fine associations I have had, and the friendships which have resulted. My fondest hope is that my retirement from office will not deprive me of the privilege of their continuation. It has been a very great honor to have

Backstage with the 1952 Trainees in SQC at the Educational Sessions.

Ladies Program Luncheon at Tubbert's. Left to right: Mrs. Leon Bass; Dr. George Valley, speaker; Mrs. Raymond S. Saddoris.

Hugo. A. Weissbrodt, Saturday Luncheon Speaker.

served as your President, and my appreciation of this honor goes far beyond the power of mere words to express."

The President's Report provided a fitting introduction for the presentation of the Shewhart Medal to Mr. George DeForest Edwards, the first president and guiding spirit in the initial establishment and organization of the American Society for Quality Control. The Citation gives the reasons for the selection of Mr. Edwards as Medalist as follows:

"In recognition of his contributions to the science of quality control as a director of basic pioneer development work, his expert guidance of the wartime program which resulted in widespread introduction of new acceptance quality control procedures in military procurement, and his leadership in organizing the American Society for Quality Control and in developing it into a strong professional society. His many activities have contributed heavily to the advancement of quality control as a new engineering profession."

Mr. Edwards was introduced to the Convention as Medalist by Dr. Martin A. Brumbaugh, whose presentation speech reads as follows:

"To present the 1951 Medalist is a privilege and a pleasure.

"Native son of Ohio; Graduate of Harvard, Magna cum laude; outstanding engineer; Inventor; Executive; Pioneer in all phases of quality control; Guiding spirit of the American Society for Quality Control; Friend.

"First employed at Western Electric in 1914 in Chicago, he was subsequently transferred to central engineering in New York. There he worked on design of long distance land and underwater cables. A number of the transmission and circuit devices are his inventions. During World War I he contributed in major ways to communication devices for submarine detection. Subsequently in charge of long-lines cable installation in Sweden, he returned in 1924 to Western Electric Engineering Dept. which in 1925 became the newly formed Bell Telephone Laboratories.

"As Inspection Engineer, and subsequently Director of Quality Assurance, he was an integral part of the team that developed the scientific approach to the problems of inspection and quality engineering. Out of this Department came Shewhart's initial presentation of the control chart and the concept of control of quality during production; the Consumer's and Producer's risks, lot tolerance, process average, and the A.O.Q.L. concept as the basis for minimized single, double, and multiple sampling plans; the demerit system and classification of defects in quality rating. The basic publications of quality control, Shewhart's "Economic Control of Quality of Manufactured Product" and "Statistical Method from the Viewpoint of Quality Control," Dodge and Romig "Sampling Inspection Tables," and a series of monographs that continue to be important, constitute the public record of the work of the Department. From this Department also came the inspiration and technical assistance which aided in producing the A.S.T.M. Manual on Presentation of Data, and the "Z" Quality Control Standards of the American Standards Association.

"Early in World War II he went on loan as consultant for quality control to the Secretary of War. Successively he guided and spark-plugged the development, installation, and operation of acceptance sampling procedures for war materiel in Army Ordnance, Signal Corps, and finally in all branches of the Army through the Army Service Forces Headquarters program. This program produced the Army's "Standard Sampling Inspection Tables" and the "Standard Inspection Procedures, Quality Control," the basis for acceptance sampling inspection in the facilities of prime contractors and sub-contractors, and the forerunner of Military Standard 105A.

"In recognition of this service he received in 1944 a merit citation from the Ordnance Department and in 1947 a

certificate for distinguished service from the War Department. Since the Korean incident he has again been called to Government Service to manage a program for the control of quality of large calibre ammunition.

"In 1945 he became interested in the attempts that were being made to form a national quality control organization. His work with the various groups, although quite inconspicuous, was the real unifying force, his was the leadership which led on February 16, 1946 to the formation of the American Society for Quality Control. Elected the Society's first president, he steered the infant organization through a difficult initial existence to stability and virility at the close of his term in 1948. Able and judicious counsellor, tireless worker, he has been a bulwark of strength to his successors, and at present is Chairman of the Constitution and By-Laws Committee, Member of the Sectional Representation Committee, Fellow, and Honorary Member of the Society.

"Ladies and gentlemen, I am delighted to present as the Shewhart Medalist for 1951, George De Forest Edwards."

Mr. Edwards, having been so ably presented, responded with the following introductory remarks. The text of his Medalist Address appears elsewhere in this issue.

"Once more, my favorite Society—the apple of my eye so far as Societies go—has seen fit to confer on me one of its highest honors.

"To tell you merely that I am touched by this further evidence of your regard, would be a gross understatement.

"To imply that I in any way deserve it, would be crass demagoguery.

"As many of you know, I had quite a bit to do, some years ago now, with working out the general philosophy which was to be behind the Shewhart Medal. With the aproval of your Executive Committee and the concurrence of your Board of Directors, I appointed the first Shewhart Medal Committee and drafted its "terms of reference."

"I have not been able to lay my hands on a copy of that document, but it is my recollection that, in essence, it directed the Committee to confer the Medal, not more than once each year, on that person whom it found to have contributed most to the underlying mathematical, statistical, and philosophical foundation of Quality Control.

"This background for the Medal was calculated to do honor to those who might succeed in emulating the distinguished work of the inventor of the Control Chart, for whom the Medal was named.

"Incidentally, this basis of selection would be expected to elicit from each Medalist a philosophical address of acceptance which would be sound and enduring in character—one which would warrant preservation in the annals of the Society and in the libraries of its members.

"Quite frankly, I am far from convinced that such small contributions as I may have been able to make to Quality Control meet the prerequisites for a Shewhart Medalist as I have described them. But I am much humbled by the apparent conviction of your Committee that this is the case, as well as by my problem in presenting to you a sufficiently erudite address of acceptance.

"I assure you that I am deeply appreciative of this high honor you have bestowed upon me, and I thank you from the bottom of my heart.

"Since I retired as your President four years ago, I have consistently refused all invitations to address ASQC meetings of any kind whatsoever—because I have been convinced that you heard enough from me during my more than two years in the Presidency. In fact, I addressed so many evening meetings during that period, that I heard rumors to the effect that I had become a pillar of brass by day and a cloud of gas by night.

"By choosing me as your Medalist, your Committee has now succeeded in forcing me to make a speech. But whether your Committee has won more than rather hollow success, remains to be heard."

The Shewhart Medalist Address was followed by the continuation of the annual meeting of the society.

The chief teller, Dr. Ellis R. Ott, reported the results of the election and commented upon the apparent contradiction between the society's advocacy of sampling to replace 100% inspection, and its attempt to get every member to vote in the election, rather than using a good random sample. With this comment, and a related reservation about the accuracy of the count, he reported the results of election to be the endorsement of the official slate. The following officers were then installed by the retiring president, Wade R. Weaver: *President*—Simon Collier, Director of Quality Control, Johns-Manville Corporation, New York; *Vice-Presidents* — Arthur Bender, Jr., Quality Engineer, Delco-Remy Division, General Motors Corporation, Anderson, Indiana; Raymond S. Saddoris, Director of Quality, A. O. Smith Corporation, Milwaukee, Wisconsin; Dr. Julian H. Toulouse, Chief Engineer, Quality and Specifications Department, Owens-Illinois Glass Company, Toledo, Ohio; *Executive Secretary* — Edward B. Haden, Quality Control Director, Esterbrook Pen Company, Camden, New Jersey; *Treasurer*—Paul A. Robert, Assistant Quality Manager, International Business Machines Corporation, Endicott, New York.

After these activities, the meeting adjourned, to be followed by committee meetings which lasted well into the night.

FRIDAY

Although many of the committee meetings extended well into Friday morning, the bulk of the membership were able to avail themselves of Syracuse's hospitality and so off to bed. There were different committee meetings held as scheduled on Friday morning at 8:30, and the exhibits and the educational sessions opened at 9:00.

Technical sessions scheduled for both morning and afternoon brought the peak daily attendance, which was reflected in the luncheon participation, the largest meal served.

The opening announcements were followed by the introduction of Mr. Ken-ichi Koyanagi, Managing Director of the Japanese Union of Scientists and Engineers, who expressed his pleasure at being able to attend the Convention and to pass out copies of his pamphlet "Statistical Quality Control in Japanese Industry". His treatise deals with the development of Quality Control techniques in Japanese Industry, and is very illuminating.

Brigadier General Ralph H. Tate (U. S. Army Retired), President of Camillus Cutlery Company, Camillus, New York, delivered a stirring address on the "March of Communism". He was introduced by Mr. Carl F. B. Roth, President of Aircooled Motors, Incorporated, Liverpool, New York, who revealed that Mr. Tate had been associated with the Russians from 1941 to 1947, including two years "behind the Iron Curtain", as Deputy U. S. Commissioner for Austria.

Committee meetings took up a part of the post-session evening, but more than 600 delegates found it worth their while to attend the

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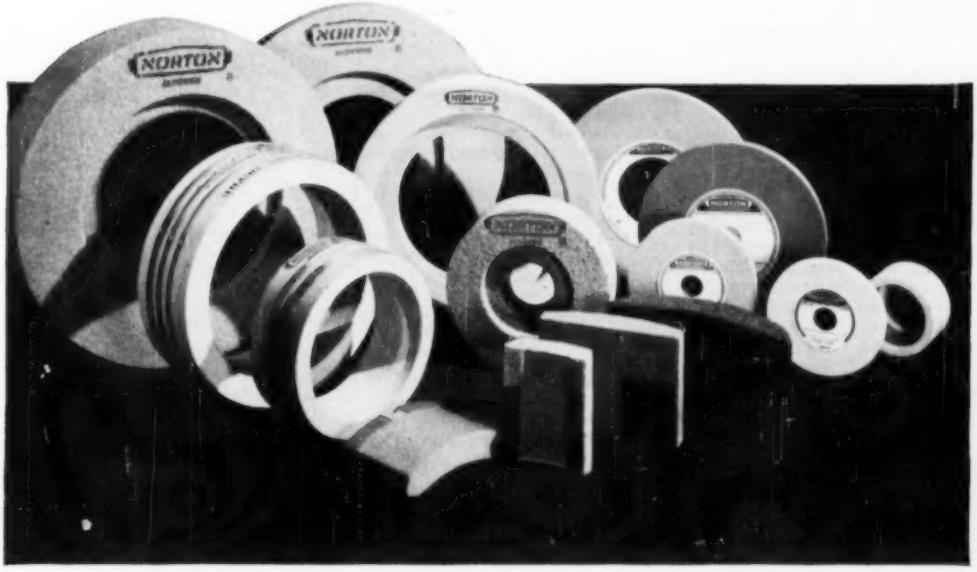

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Social Evening function in the Ballroom of the Hotel Syracuse. Amid community singing and ample refreshments, good fellowship, annual reunions, and general enthusiasm maintained an initial momentum from about 9:30 PM until well past 1:00 AM.

Numerous gifts were presented as door prizes by various local concerns, including Bristol Laboratories, The Borden Company, Camillus Cutlery Company, General Electric Company, and Will and Baumer Candle Company. Everyone had a genuine good time in keeping with the traditions set for these Social Evening gatherings by previous ASQC conventions.

SATURDAY

The final day of the Convention dawned sunny, but hazy; giving promise to the fulfillment of the threats of the weather bureau. However, committees held their scheduled meetings and the sessions got under way with the sun still shining.

At noon, the crowd had noticeably thinned out, many having had to catch planes or trains; but there still remained about a thousand people to eat lunch and hear the final address of the Convention. Mr. Wade Weaver proceeded to introduce the Works Manager of the Fort Wayne, Indiana, Works of the International Harvester Company, Mr. Hugo Weissbrodt. Mr. Weissbrodt, a fellow of ASQC, mentioned several of his experiences in handling quality control problems and people, and demonstrated very effectively the truth of the title of his speech "Quality Control, the Key to Improved Employee Relations".

The main business of the Convention over and done, the majority of the delegates either visited the exhibits for the last time, or headed for home. The directors of the Society went into executive conference at 2:00 PM, followed by a banquet, ratified the actions of the officers, and made plans for the coming year. At about this time, it began to rain and the able staff of the Onondaga County War Memorial Auditorium swung into action to prepare for another Convention.

LADIES PROGRAM

Concurrently with the main proceedings, the Ladies Program was in full swing. On Thursday afternoon, most of the ladies went on a walking tour of the Onondaga Pottery plant, where they observed the steps in the manufacture of table chinaware; they were so impressed with what they saw that one of the two buses used for the return trip had to be diverted to the Pottery's sales outlet, several miles away.

On Friday, all the ladies attended what one described as an "overstuffed" luncheon at Tubbert's, where the tables were divided between the "shrimps" and the "chickens". Favors of hand-decorated ash trays from the Pottery were added to red carnation corsages to make the gathering even more colorful than the array of spring hats and clothing would otherwise have done. The ladies "technical session" on "Bugs and Drugs" was presented by Dr. George Valley of Bristol Laboratories, who entranced his audience by pulling examples of different forms of antibiotics in bottles, boxes, etc., from his pockets and briefcase as the talk progressed. When he was finished with his excellent dissertation on dosages, efficacy, and comparative usages of different antibiotics, he gave the ladies an idea of what the future may have in store for humans—most diseases subject to control by medicine—and had a small mountain of samples piled on the table before him. There were 90 participants in this program.

EXHIBITS AREA

The Exhibits Area, in the basement of the Auditorium, was bounded on the south by the dining area, on the north by the ASQC Booth, on the east by the Book Booth, and on the west by the Transactions Booth. The Book Booth was visited by most of the visitors to this area, who talked to nine authors and nine book advisers, and purchased many different books from the excellent display. The Transactions Booth was similarly crowded, as more than 1200 copies of the Proceedings were sold.

During the three days 547 people visited the exhibits in addition to those regularly enrolled at the Convention. The number of booths occupied, 57, and the number of exhibitors, 36, made this display the largest ever to appear at a quality control convention. The companies who had displays were as follows:

American Cystoscope Inc.
Ann Arbor, Mich.

American SIP Corporation
New York, New York

Bausch & Lomb Optical Co.
Rochester, New York

Boice Mfg. Co.
Staatsburg, N. Y.

Brown & Sharpe Mfg. Co.
Providence, R. I.

Brush Development Co.
Rochester, New York

Carrier Corporation
Syracuse, New York

Collins Micro-Flat Co.
Los Angeles, Calif.

Cosa Corporation
New York, N. Y.

Do-All Company
Des Plaines, Ill.

Elliott Service Co.
Mt. Vernon, N. Y.

Engineers Specialties
Buffalo, N. Y.

Federal Products Corp.
Providence, R. I.

Ford Motor Company
Dearborn, Michigan

Friden Calculators
San Leandro, Calif.

General Electric Company
Syracuse, New York

Graham-Mintel Instrument Co.
Cleveland, Ohio

Greenfield Tap & Die Corp.
Greenfield, Mass.

F. T. Griswold Mfg. Co.
Wayne, Penna.

Herman Stone Co.
Dayton, Ohio

Horberg Gage Company
Bridgeport, Conn.

Industrial Scientific
New York, N. Y.

International Harvester
Chicago, Ill.

Jones & Lamson Company
Springfield, Vt.

Johnson Gage Company
Bloomfield, Conn.

Magnaflux Corporation
Chicago, Ill.

Marchant Calculators
Syracuse, New York

Micrometrical Mfg. Company
Ann Arbor, Michigan

Monroe Calculators
Orange, N. J.

National Tool Co.
Cleveland, Ohio

Nilsson Gage Company
Poughkeepsie, N. Y.

Oberdorfer Foundries
Syracuse, New York

Sheffield Corporation
Dayton, Ohio

L. S. Starrett Company
Athol, Mass.

Sylvania Electric Co
Seneca Falls, N. Y.
Taft-Pierce Mfg. Co.
Woonsocket, R. I.

In attendance at the Convention, in addition to our many Canadian friends, were several visitors from across the seas. Their homelands included South Africa, Switzerland, Belgium, Israel, Japan, and Sweden. The local newspapers played up this aspect of the Convention and as the last article to appear, published interviews with some of these travelers.

These evidences that word of our use of quality control techniques is spreading around the world are very heartening, and highlight the growth of the Society's membership in our own country.

ONE-DAY SQC CONFERENCE

The Fourth Annual All-Day Conference on Quality Control sponsored by the Metropolitan Section of the American Society for Quality Control and Rutgers University, the State University of New Jersey, will be held on Saturday, September 13.

The three simultaneous panels will meet at 9:45 A.M. on the Men's Campus of the State University in New Brunswick. Mr. Thomas A. Budne, Quality Control Statistician for E. R. Squibb and Sons, New Brunswick, is Chairman of the Conference.

ERRATA NOTE

In the May, 1952, issue of IQC, the following errors should be noted.

1. On p.35, delete the word "Whitin" from the caption for Figure 1.
2. On p.37, the chart shown as Figure 6 should appear as the chart for Figure 7.
3. On p.37, the chart shown as Figure 7 should appear as the chart for Figure 9 on p.38.
4. On p.38, the chart shown as Figure 9 should appear as the chart for Figure 6.

Captions on Figures 6, 7, and 9 are correct as shown.

These corrections have been made in the separate reprints of this paper furnished the authors.

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Importance of Quality Control in Industry

R. R. RAUSCH

Vice-President and Executive Assistant to the President, Willys-Overland Motors, Inc., Toledo, Ohio

Constant change is one of the characteristics of American industry. All over the world, in every field of activity, engineers and scientists are lying awake at night to figure out improved methods for reducing the cost of manufacturing toward the goal of better products for the consumer. This constant change is the "yeast" which has raised the standard of living of our people until today we enjoy, unchallenged, the highest standards in the world. In recent times, American productivity has increased 3% per year until today, we are truly approaching . . . "A chicken in every pot, two cars in every garage and for every child, a bicycle" . . . All of this while we wage a first-class military expedition in Korea and arm ourselves against the possibility of war. This great flood of material coming from our industry is the fruit of grafting together the technical skills and investment capital with the cement of management.

The technical skills which we as a nation possess would have been impossible without the direct contribution of technical organizations such as the American Society for Quality Control. The people of this country owe a great debt to men and women like those in ASQC who unselfishly share their knowledge and experience through meetings, conventions, publications, committees, etc. Sometimes your activities can be quite an annoyance to your associates. You point out errors in the way we have been doing things. You suggest we change our methods. This means we must learn new techniques and acquire new skills—and we don't always like that. It would be so much easier if we could coast along, but the constant driving challenge of competition makes us listen to you. The inefficient methods of the past cannot continue to exist once a better method is known. Constant change, therefore, becomes one of the major characteristics of American industry.

One of the most profound changes in recent years has been the advent of statistical methods for the control of quality. Inspection has always been somewhat of a sore spot in industry. We attempted to control our processes by examining the work produced by them but the data obtained meant different things to different people. Important operations sometimes were left unattended while we became concerned with unimportant details. The particular mood of the inspector was often as important as the inspection results. A sixth sense, based on years of experience, was necessary to judge the hair-line distinctions between good material and scrap. As a result, scrap and rework often became the largest item of manufacturing loss and frequently the quality of the product was questionable.

With the advent of statistical inspection methods, we obtained accurate techniques to measure quality, somewhat similar to our measurement of length, hardness or tensile strength. Opinions and sixth senses were no longer required. For the first time, we had factual data upon which controls could be established. It is not surprising that the Government quickly adopted these devices for ordnance procurement. A properly administered scientific inspection method, where acceptable quality levels are accurately stated, can do much to eliminate the defective judgment of green or inexperienced inspectors. It will give assurance that the final product will perform its service function with the least possible penalty upon the cost of manufacturing.

The Government is setting acceptable quality levels for our productions. Through the use of statistical methods, we can measure the process capability of our facilities to know beforehand the ability of our processes to meet this quality level and if changes are necessary, we can quite accurately determine the expense of altering these facilities. Most important, we can establish statistical process controls so as to have prior assurance that the material will pass the Government inspection procedures and thereby eliminate the cost of scrap or rework.

It is particularly significant to discuss this technique now because of the vital importance it will play in the prevention of waste of critical materials. By the statistical and mathematical approach to the control of quality, we are able to control the processes of product manufacture at the operation. By the sure and positive means of designating the exact quality level of a process we are able to detect immediately the slightest variation from the quality specifications. The defective process can be stopped until such changes as are necessary to guarantee manufacturing within the specification can be made. By this method, materials are not produced which during the course of floor inspection or at final inspection may be found to be unacceptable and therefore scrap. It is by these means that millions of dollars worth of critical materials can be saved, which in many instances may not be readily replaceable.

In these times when extraordinary importance is placed on the conservation of manpower, many hours of labor are also saved, which can be transferred to useful manufacturing of other quality merchandise.

It is, therefore, of extreme importance that all serious minded individuals at all levels of management responsibility should further this program in their manufacturing facilities.

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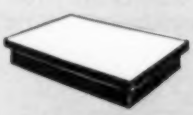
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Use of Random Numbers

FRANK PROSCHAN

Statistical Engineering Laboratory, National Bureau of Standards,

As part of the Government's contractor-checking program, Anna List, lovely blonde chemist, was asked to analyze five samples selected at random from among 27. She, believing that "random" meant "haphazard," selected sample numbers 5, 10, 12, 20, and 23.

Just as she was about to weigh out 3-gram samples from each of the 5 sample bottles, in rushed Statler Symington Titian, troubleshooter for the U. S. Control Laboratory.

"Stop!" exclaimed Stat S. Titian, "do you realize that the answer you get will be biased?"

"Easy, Stat," replied Anna, somewhat amused at Stat's emotional outburst, "first of all, don't use nasty words like 'biased.' Secondly, explain why my answer would be biased."

"Anna, do you realize that of the five samples you have selected, three are multiples of 5?"

Anna pretended to tear in two the picture of Stat that she kept on her desk. "Really Stat, sometimes you can be so trying. Will you tell me why that should make the least bit of difference?"

Stat, certain that his irresistible logic would triumph in the end, replied calmly, "I've just found out that the chief chemist of the lab we're checking habitually runs every fifth sample, while the others are run by the chemists under him. Since the chief chemist happens to be a Nobel Prize winner in platinum assaying, while the others are clerks who have had two weeks of training in chemical analysis, you can be sure that a group of five samples, three of which represent the work of the Nobel Prize Winner, and two of which represent the work of the clerks, will not lead to a correct conclusion concerning the average quality of assaying in the contractor's laboratory where routinely only 1/5 of the samples are analyzed by the Nobel Prize winner and 4/5's are run by the clerks."

"Oh, Stat, how correct you are in your analysis! I'm so glad I called you in first, before selecting these random samples unscientifically." Anna generously gave herself some of the credit for foresight. "How should I have selected these samples?"

"Suppose, as in your case, you knew nothing of the operations of the laboratory. The safest way, then, is to use a table of random numbers."

Anna List burst into laughter. "You mean you statisticians have actually made up a table of 'random' numbers? How droll!"

Stat S. Titian winced at the sacrilege of laughter concerning a statistical table. "Anna, you saw how easily results may be biased when a set of numbers is selected supposedly at random by the human mind." Stat looked at her doubtfully.

"O. K., Stat, how would I use this table* in our present problem?"

"Simply select a place in the table at random and then read across (or down). Since we are interested in selecting five at random from among 27, we would consider each successive two-digit number including those of the type '07'. We would keep the first five numbers encountered in the interval 01 to 27—any numbers over 27 would be ignored, as would be any repeated occurrences of a number already selected. Thus, if we started at 03 in the table (16th row, 14th column) we would successively select

03, 17, 13, 04, 07

by proceeding to the right."

"How wonderful you and statistics are, Stat!" Anna's large blue eyes shone with admiration. "But, Stat, suppose we were selecting, say, 13 at random out of 175. How would we proceed?"

Stat could explain for hours when Anna looked at him that way. (Un-

*The table accompanying this paper is a portion of a 15,000-digit table of random numbers in Fisher and Yates *Statistical Tables for Biological, Agricultural and Medical Research*, published by Oliver and Boyd Ltd. Edinburgh. The portion used is from pp. 104-109 of the 3rd ed., 1948. I am indebted to Professor Ronald A. Fisher, Cambridge, to Dr. Frank Yates, Rothamsted, and to Messrs. Oliver and Boyd for their permission to reproduce this portion of their tables.

A TABLE OF RANDOM NUMBERS

Note: Another table of random numbers (12,500 digits) is given in W. J. Dixon and F. J. Massey, Jr., *Introduction to Statistical Analysis*. McGraw-Hill Book Company, Inc., New York, 1st ed., 1951, pp. 290-294. If frequent use is to be made of a table of random numbers, the Fisher and Yates or the Dixon and Massey tables should be used, since they are considerably larger than the table given in this paper. Clearly, in using any table of random numbers, care should be taken not to start at the same spot too often.

More specialized are the Tables of Random Permutations of 9 and of 16, W. G. Cochran and G. M. Cox, *Experimental Designs*. John Wiley & Sons, Inc., New York, 1st ed., 1950, pp. 422-427 and 428-440, respectively. These tables are useful when a random *arrangement* is desired for any number of objects from 2 to 16.

03	47	43	73	86	36	96	47	36	61	46	98	63	71	62	33	26	16	80	45	60	11	14	10	95
97	74	24	67	62	42	81	14	57	20	42	53	32	37	32	27	07	36	07	51	24	51	79	89	73
16	76	62	27	66	56	50	26	71	07	32	90	79	78	53	13	55	38	58	59	88	97	54	14	10
12	56	85	99	26	96	96	68	27	31	05	03	72	93	15	57	12	10	14	21	88	26	49	81	76
55	59	56	35	64	38	54	82	46	22	31	62	43	09	90	06	18	44	32	53	23	83	01	30	30
16	22	77	94	39	49	54	43	54	82	17	37	93	23	78	87	35	20	96	43	84	26	34	91	64
84	42	17	53	31	57	24	55	06	88	77	04	74	47	67	21	76	33	50	25	83	92	12	06	76
63	01	63	78	59	16	95	55	67	19	98	10	50	71	75	12	86	73	58	07	44	39	52	38	79
33	21	12	34	29	78	64	56	07	82	52	42	07	44	38	15	51	00	13	42	99	66	02	79	54
57	60	86	32	44	09	47	27	96	54	49	17	46	09	62	90	52	84	77	27	08	02	73	43	28
18	18	07	92	46	44	17	16	58	09	79	83	86	19	62	06	76	50	03	10	55	23	64	05	05
26	62	38	97	75	84	16	07	44	99	83	11	46	32	24	20	14	85	88	45	10	93	72	88	71
23	42	40	64	74	82	97	77	77	81	07	45	32	14	08	32	98	94	07	72	93	85	79	10	75
52	36	28	19	95	50	92	26	11	97	00	56	76	31	38	80	22	02	53	53	86	60	42	04	53
37	85	94	35	12	83	39	50	08	30	42	34	07	96	88	54	42	06	87	98	35	85	29	48	39
70	29	17	12	13	40	33	20	38	26	13	89	51	03	74	17	76	37	13	04	07	74	21	19	30
56	62	18	37	35	96	83	50	87	75	97	12	25	93	47	70	33	24	03	54	97	77	46	44	80
99	49	57	22	77	88	42	95	45	72	16	64	36	16	00	04	43	18	66	79	94	77	24	21	90
16	08	15	04	72	33	27	14	34	09	45	59	34	68	49	12	72	07	34	45	99	27	72	95	14
31	16	93	32	43	50	27	89	87	19	20	15	37	00	49	52	85	66	60	44	38	68	88	11	80
68	34	30	13	70	55	74	30	77	40	44	22	78	84	26	04	33	46	09	52	68	07	97	06	57
74	57	25	65	76	59	29	97	68	60	71	91	38	67	54	13	58	18	24	76	15	54	55	95	52
27	42	37	86	53	48	55	90	65	72	96	57	69	36	10	96	46	92	42	45	97	60	49	04	91
00	39	68	29	61	66	37	32	20	30	77	84	57	03	29	10	45	65	04	26	11	04	96	67	24
29	94	98	94	24	68	49	69	10	82	53	75	91	93	30	34	25	20	57	27	40	48	73	51	92
16	90	82	66	59	83	62	64	11	12	67	19	00	71	74	60	47	21	29	68	02	02	37	03	31
11	27	94	75	06	06	09	19	74	66	02	94	37	34	02	76	70	90	30	86	38	45	94	30	38
35	24	10	16	20	33	32	51	26	38	79	78	45	04	91	16	92	53	56	16	02	75	50	95	98
38	23	16	86	38	42	38	97	01	50	87	75	66	81	41	40	01	74	91	62	48	51	84	08	32
31	96	25	91	47	96	44	33	49	13	34	86	82	53	91	00	52	43	48	85	27	55	26	89	62
66	67	40	67	14	64	05	71	95	86	11	05	65	09	68	76	83	20	37	90	57	16	00	11	66
14	90	84	45	11	75	73	88	05	90	52	27	41	14	86	22	98	12	22	08	07	52	74	95	80
68	05	51	18	00	33	96	02	75	19	07	60	62	93	55	59	33	82	43	90	49	37	38	44	59
20	46	78	73	90	97	51	40	14	02	04	02	33	31	08	39	54	16	49	36	47	95	93	13	30
64	19	58	97	79	15	06	15	93	20	01	90	10	75	06	40	78	78	89	62	02	67	74	17	33
05	26	93	70	60	22	35	85	15	13	92	03	51	59	77	59	56	78	06	83	52	91	05	70	74
07	97	10	88	23	09	98	42	99	64	61	71	62	99	15	06	51	29	16	93	58	05	77	09	51
68	71	86	85	85	54	87	66	47	54	73	32	08	11	12	44	95	92	63	16	29	56	24	29	48
26	99	61	65	53	58	37	78	80	70	42	10	50	67	42	32	17	55	85	74	94	44	67	16	94
14	65	52	68	75	87	59	36	22	41	26	78	63	06	55	13	08	27	01	50	15	29	39	39	43
17	53	77	58	71	71	41	61	50	72	12	41	94	96	26	44	95	27	36	99	02	96	74	30	83
90	26	59	21	19	23	52	23	33	12	96	33	02	18	39	07	02	18	36	07	25	99	32	70	23
41	23	52	55	99	31	04	49	69	96	10	47	48	45	88	13	41	43	89	20	97	17	14	49	17
60	20	50	81	69	31	99	73	68	68	35	81	33	03	76	24	30	12	48	60	18	99	10	72	34
91	25	38	05	90	94	58	28	41	36	45	37	59	03	09	90	35	57	29	12	82	62	54	65	60

fortunately, he sometimes did.) "We would simply start someplace in the table and then consider successive three-digit numbers and keep the first 13 different numbers from 001 to 175."

"Stat, I'm going to reform right now! Whenever I have to select samples at random, or in general, select numbers at random, I'm going to use this table and not my womanly intuition!"

Moral: When a set of m numbers is to be selected at random from among n (where n is a d-digit number), simply start some place in the table and proceed consistently in any direction, considering successive d-digit numbers. Ignoring d-digit numbers greater than n, select the first m different numbers found in the interval 1 through n.

Quiz

1. Select 12 random numbers among 37.
2. Select 19 random numbers among 111.

The Armed Services, Industry, and Quality Control*

E. H. MAC NIECE

Director of Quality Control, Johnson & Johnson, New Brunswick, N. J.

WITHIN the past decade American industry has awakened to the fact that it cannot make large quantities of product and later sort the good from the bad. The speed, volume, and complexity resulting from applied science has demanded that management itself apply scientific methods. This demand has been felt in all management activities and particularly in the control of quality. More and more decisions are being based on numerical values. Such decisions are, of course, more accurate and dependable.

For the conception of the fundamental principles of Quality Control we will be everlastingly indebted to Dr. Walter A. Shewhart and his pioneering associates. For propagation of these principles, the American Society for Quality Control has carried the torch that cast light on the subject and kindled great enthusiasm for this relatively new but vitally important management tool. Where do the Armed Services fit into this picture? What does Quality Control owe them? The answer to these questions undoubtedly is that the Armed Services have been the spearhead in forcing acceptance and application of the principles of statistical Quality Control. To support this statement suppose we examine the work done by General Leslie Simon, Commander B. L. Lubelsky, Dr. William R. Pabst, Jr., Dr. John H. Curtiss, and many others.

*Paper presented at an all-day meeting on Military Procurement, sponsored by the Chicago Section, ASQC, September 19, 1951.

THE CONCEPT OF LOT TOLERANCE

Probably the greatest single accomplishment of this combination of men was the gaining of acceptance of the concept of *lot tolerance*. Seldom do we find an individual who does not understand and accept item or unit tolerances. We all know that there is variation in all things; and we do not hesitate to specify that a dimension, for example, shall be plus or minus a certain figure. Many otherwise well informed executives, however, have had difficulty in accepting the concept of lot tolerance. Since tolerance has already been allowed for variation in units, it has been difficult for them to understand why any lot should be accepted when a small percentage of the units in it are nonconforming with the specification.

The ordnance work of General Simon and others for the Normandy Invasion proved beyond any doubt that economic, calculated risks, based upon scientifically sound statistical sampling, can be accurately predicted. When such critical ordnance items yielded to Quality Control treatments, the concept of lot tolerance was accepted for a broad range of military items.

The work of Dr. Curtiss and others in modifying and combining the work of Dr. H. G. Romig, Harold F. Dodge, and the Columbia Statistical Group in MIL-STD-105A will almost force the acceptance of the lot tolerance concept in all areas where it should be applied.

Let us see what comes of making a critical comparison of operations of the Armed Services Procurement Teams at the beginning of World War II and today. Johnson & Johnson serves all branches of the military through the Armed Services Medical Procurement Agency. Comparisons will, therefore, deal primarily with this agency but will be quite typical of the other agencies.

BETTER SPECIFICATIONS

First, let us trace the evolution of specifications because they are so essential to the control of quality. We can not control anything that is not properly specified. Neither can we reproduce it. In the early 1940's specifications were not much more than purchase descriptions as to size, type, etc. with the customary ambiguous escalator clauses such as, "everything must be first class; substantially free from foreign matter; a good white, etc." Moreover, when the Army wanted an item to be round and wrapped in Kraft paper, the Navy wanted it square and wrapped in tar paper.

Then came the era of "Joint Specifications." These standardized many items used by the different services and they were more specific. It would be difficult to assess the savings from the use of these joint specifications, but I know that within the limitations of my field of activity they must have been great.

Recently I reviewed a new proposed MIL Specification sent out by the new General Services Organiza-

tion. The specificity was perfect. There was no hedging—no escalator clauses. Included with it was a production routing listing the operations and their sequence. There was a reference of where to obtain the patterns. There was a requirement that the procurement agency specify a lot tolerance in invitations to bid. And finally, MIL-105A was specified for use in determining the quality levels. This is the realization of a fond dream by industry. We look forward to a brighter future in which needed specificity will make results predictable, reproducible, and economical.

CLOSER COOPERATION BETWEEN INDUSTRY AND THE MILITARY

Next, let us examine the improved cooperative skills developed by industry and the military. In World War I a contractor would not think of suggesting improved methods or quality to the Armed Services for fear of getting his ears beaten back. In World War II there bloomed a cooperation between contractor and the Armed Services that surpassed anything heretofore imaginable. Contractors were brought into preliminary discussions. They were given contracts to develop many of the requirements. The procurement agencies performed an almost miraculous task in coordinating this work. Today, in arrangements like Rand, teams of scientists, engineers, statisticians, mathematicians, and military men are planning our military needs and stratagems for any eventuality. This is the broad scale cooperation.

Then there is the front line cooperation in specification, bidding for contracts, and acceptance testing and inspection of military production. Each industry should review its proposed specifications and be a part of their development. We have found that all invitations to bid should be reviewed by a person in Quality Control or someone who knows our process capabilities and our own specification limits before costs are established.

Some people look upon the Armed Services Resident Inspector as the individual who takes all the joy out of life. This is a misconception. The inspector is the vital liaison link in the whole system. I recall sitting down with a newly arrived resident inspector at the beginning of World War II. I asked, "What is the most important thing to you in your

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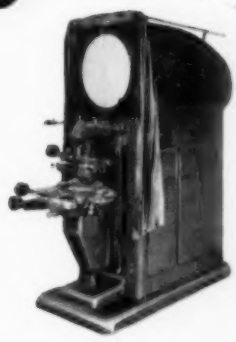
1



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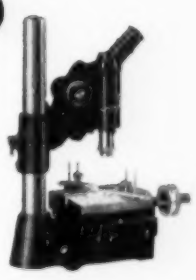

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work?" The answer was, "To never have a depot rejection." I asked, "Why?" The answer was, "Because a depot rejection dislocates procurement planning and may contribute to losing the war. It would also count against my record."

I immediately realized that I also wanted what the inspector wanted and for the same reasons. Within two minutes we had established common objectives. The rest was simple. How could we accomplish these objectives?

The primary requirement was honesty. Keep the inspector informed of all suspected deviations. Remember that the inspector is a specialist in interpreting specifications. He is also the liaison link with the procurement team. On many occasions our resident inspector went to the Armed Services Medical Procurement Agency Offices with samples and obtained official interpretations of specifications *before* thousands of dollars of time and materials were wasted to produce non-acceptable goods.

What did this accomplish? It accomplished our primary objective. We went all through the war without a single depot rejection. To be sure, we were not perfect. We had rejections in process where small segments of production were impounded and heavily sampled to know the real risks. The whole arrangement was a dynamic one in that we immediately made adjustments and got back in control. We had a few terminal rejections in our own factories too, but procurement plans were never dislocated; and we never had the added cost and embarrassment of depot rejections.

As a secondary accomplishment, it is correct to say that the maintenance of these same disciplines permitted us to continue our service to the Armed Forces in times of peace when there was no resident inspector present.

LOOKING AHEAD

So much for Quality Control and the Armed Services and industry, past and present. What does the future hold for us?

The effective expenditure of 50 billions per year for the next three years is a gigantic undertaking. The objective of 18 full divisions of the Army, 1,100 vessels for the Navy, and 95 Air Force Groups (which will probably be augmented) presents

many problems in logistics for the Armed Forces Procurement Agencies. It presents equally difficult problems and a staggering load for industrial procurement executives. These men will have the responsibility for the purchase and introduction of the correct raw materials and components that enter into production processes. When we consider the fact that from 40 to 50 percent of the cost of military, as well as civilian, goods is for raw materials and purchased finished components, we get some idea of the prodigious job ahead for American, industrial, purchasing executives. They have never failed. They never will, but we must help them pull the load. Quality control executives must dedicate themselves to provide for prompt and accurate acceptance determinations. They must also use all other contrivances to help the procurement function.

Industry recognizes that it would be only fatuous to produce or give less than that specified by the Armed Services. In the first place, armed with MIL-105A the risks of rejection are too great for comfort. Secondly, ineffective contributions to procurement programs only increase taxes. As it is, the so-called excess profits taxes make it scarcely worth while to try for profits that will only increase the levy. Make no mistake about it, industry is vitally interested in getting the right material to the Armed Services at the right time and at the right cost, so that we can fulfill the needs and get out from the yoke of our present staggering taxation. If the effective pattern set by military procurement agencies is carried into civilian government spending, we can all benefit.

The years ahead will yield increasing benefits both military and civilian. Prediction, specification, and production will reach new and higher levels of effectiveness as the science of Quality Control is improved and more broadly accepted. Of equal importance is the improvement and extension of cooperative skills. The teams of the military agencies and industry will give full service, and no problems that arise will cause them to fail.

Tables for Constructing and for Computing the Operating Characteristics of Single-Sampling Plans

J. M. CAMERON

National Bureau of Standards

THIS note presents tables for computing the operating characteristics of single-sampling plans and for constructing sampling plans having desired operating characteristics.

The number of defective units in a sample from a lot determines whether the lot will be accepted on the basis of the sample. Obviously the smaller the percentage of defective items produced by the process from which the lot originated, the more likely the lot is to be accepted. An operating characteristic curve (OC curve) is a graph showing how the probability of acceptance depends upon this fraction defective.

An OC curve for a single-sampling plan with sample size n and allowable number of defectives c can be constructed from Table 1 by dividing each entry in the row for the given c by the number n. The result of each division is the fraction defective, p, for which the probability of acceptance, P(A), is shown in the corresponding column heading. Table 1 provides 13 paired values of p and P(A) and these can then be used to plot 13 points of the OC curve of the sampling plan.

Example: for a sampling plan calling for a sample of $n = 60$ and $c = 1$, division of the entries opposite $c = 1$ by 60 leads to the following table for plotting the OC curve of the plan.

P(A)	p	P(A)	p
0.995	0.0017	0.250	0.0448
0.990	0.0025	0.100	0.0648
0.975	0.0040	0.050	0.0790
0.950	0.0059	0.025	0.0928
0.900	0.0089	0.010	0.1107
0.750	0.0160	0.005	0.1238
0.500	0.0280		

The entries in Table 1 are values of np for which the probability of c or fewer defectives is the stated value, P(A). Table 1 therefore can be used in constructing sampling plans when for some reason the sample size is fixed at say n_0. If for some fraction defective p_0 it is desired that the probability of acceptance be, say, $P_0(A)$, simply find a value of np in Tabe 1 in the column headed $P_0(A)$ which is either equal to or just less than n_0p_0. The c corresponding to the tabular value selected, together with the given n_0, determines the sampling plan to be used.

Example: if the sample size is set at $n_0 = 100$ and it is desired to accept material with fraction defective $p_0 = .03$, 95 percent of the time (P(A) = .95), scan the column headed P(A) = .95 to find the value in the table equal to or just less than $n_0p_0 = 100(.03) = 3$. From Table 1 this turns out to be 2.613. This is opposite the value $c = 5$, the proper acceptance number.

Table 2 is used to construct sampling plans whose OC curve passes through two points. This table is an extension of the table given by Paul Peach and S. B. Littauer [1]. The selection of the two points through which the OC curve must pass requires setting forth a fraction defective p_1 which it is desired to accept with probability $1 - \alpha$ and a fraction defective p_2 which it is desired to accept with probability β. To construct a sampling plan for given α, p_1, and β, p_2 combinations find the value of the ratio p_2/p_1 in Table 2, in the column for the appropriate α and β, which is equal to or just greater than the desired ratio. Corresponding to the selected tabular value of p_2/p_1 are values for np_1 and c. The sample size is determined by dividing np_1 by p_1 and the acceptance number c is read off directly.

Example: to find the sampling plan which will accept material with fraction defective $p_1 = .01$, 95 percent of

TABLE 1—**Values of np_1 for Which the Probability of Acceptance of c or Fewer Defectives in a Sample of n is P (A).** To find the fraction defective, p, corresponding to a probability of acceptance, P(A), in a single sampling plan with sample size n and acceptance number c, divide by n the entry in the row for the given c and the column for the given P(A) .

c	P(A) = .995	P(A) = .990	P(A) = .975	P(A) = .950	P(A) = .900	P(A) = .750	P(A) = .500	P(A) = .250	P(A) = .100	P(A) = .050	P(A) = .025	P(A) = .010	P(A) = .005
0	.00501	.0101	.0253	.0513	.105	.288	.693	1.386	2.303	2.996	3.689	4.605	5.298
1	.103	.149	.242	.355	.532	.961	1.678	2.693	3.890	4.744	5.572	6.638	7.430
2	.338	.436	.619	.818	1.102	1.727	2.674	3.920	5.322	6.296	7.224	8.406	9.274
3	.672	.823	1.090	1.366	1.745	2.535	3.672	5.109	6.681	7.754	8.768	10.045	10.978
4	1.078	1.279	1.623	1.970	2.433	3.369	4.671	6.274	7.994	9.154	10.242	11.605	12.594
5	1.537	1.785	2.202	2.613	3.152	4.219	5.670	7.423	9.275	10.513	11.668	13.108	14.150
6	2.037	2.330	2.814	3.286	3.895	5.083	6.670	8.558	10.532	11.842	13.060	14.571	15.660
7	2.571	2.906	3.454	3.981	4.656	5.956	7.669	9.684	11.771	13.148	14.422	16.000	17.134
8	3.132	3.507	4.115	4.695	5.432	6.838	8.669	10.802	12.995	14.434	15.763	17.403	18.578
9	3.717	4.130	4.795	5.426	6.221	7.726	9.669	11.914	14.206	15.705	17.085	18.783	19.998
10	4.321	4.771	5.491	6.169	7.021	8.620	10.668	13.020	15.407	16.962	18.390	20.145	21.398
11	4.943	5.428	6.201	6.924	7.829	9.519	11.668	14.121	16.598	18.208	19.682	21.490	22.779
12	5.580	6.099	6.922	7.690	8.646	10.422	12.668	15.217	17.782	19.442	20.962	22.821	24.145
13	6.231	6.782	7.654	8.464	9.470	11.329	13.668	16.310	18.958	20.668	22.230	24.139	25.496
14	6.893	7.477	8.396	9.246	10.300	12.239	14.668	17.400	20.128	21.886	23.490	25.446	26.836
15	7.566	8.181	9.144	10.035	11.135	13.152	15.668	18.486	21.292	23.098	24.741	26.743	28.166
16	8.249	8.895	9.902	10.831	11.976	14.068	16.668	19.570	22.452	24.302	25.984	28.031	29.484
17	8.942	9.616	10.666	11.633	12.822	14.986	17.668	20.652	23.606	25.500	27.220	29.310	30.792
18	9.644	10.346	11.438	12.442	13.672	15.907	18.668	21.731	24.756	26.692	28.448	30.581	32.092
19	10.353	11.082	12.216	13.254	14.525	16.830	19.668	22.808	25.902	27.879	29.671	31.845	33.383
20	11.069	11.825	12.999	14.072	15.383	17.755	20.668	23.883	27.045	29.062	30.888	33.103	34.668
21	11.791	12.574	13.787	14.894	16.244	18.682	21.668	24.956	28.184	30.241	32.102	34.355	35.947
22	12.520	13.329	14.580	15.719	17.108	19.610	22.668	26.028	29.320	31.416	33.309	35.601	37.219
23	13.255	14.088	15.377	16.548	17.975	20.540	23.668	27.098	30.453	32.586	34.512	36.841	38.485
24	13.995	14.853	16.178	17.382	18.844	21.471	24.668	28.167	31.584	33.752	35.710	38.077	39.745
25	14.740	15.623	16.984	18.218	19.717	22.404	25.667	29.234	32.711	34.916	36.905	39.308	41.000
26	15.490	16.397	17.793	19.058	20.592	23.338	26.667	30.300	33.836	36.077	38.096	40.535	42.252
27	16.245	17.175	18.606	19.900	21.469	24.273	27.667	31.365	34.959	37.234	39.284	41.757	43.497
28	17.004	17.957	19.422	20.746	22.348	25.209	28.667	32.428	36.080	38.389	40.468	42.975	44.738
29	17.767	18.742	20.241	21.594	23.229	26.147	29.667	33.491	37.198	39.541	41.649	44.190	45.976
30	18.534	19.532	21.063	22.444	24.113	27.086	30.667	34.552	38.315	40.690	42.827	45.401	47.210
31	19.305	20.324	21.888	23.298	24.998	28.025	31.667	35.613	39.430	41.838	44.002	46.609	48.440
32	20.079	21.120	22.716	24.152	25.885	28.966	32.667	36.672	40.543	42.982	45.174	47.813	49.666
33	20.856	21.919	23.546	25.010	26.774	29.907	33.667	37.731	41.654	44.125	46.344	49.015	50.888
34	21.638	22.721	24.379	25.870	27.664	30.849	34.667	38.788	42.764	45.266	47.512	50.213	52.108
35	22.422	23.525	25.214	26.731	28.556	31.792	35.667	39.845	43.872	46.404	48.676	51.409	53.324
36	23.208	24.333	26.052	27.594	29.450	32.736	36.667	40.901	44.978	47.540	49.840	52.601	54.538
37	23.998	25.143	26.891	28.460	30.345	33.681	37.667	41.957	46.083	48.676	51.000	53.791	55.748
38	24.791	25.955	27.733	29.327	31.241	34.626	38.667	43.011	47.187	49.808	52.158	54.979	56.956
39	25.586	26.770	28.576	30.196	32.139	35.572	39.667	44.065	48.289	50.940	53.314	56.164	58.160
40	26.384	27.587	29.422	31.066	33.038	36.519	40.667	45.118	49.390	52.069	54.469	57.347	59.363
41	27.184	28.406	30.270	31.938	33.938	37.466	41.667	46.171	50.490	53.197	55.622	58.528	60.563
42	27.986	29.228	31.120	32.812	34.839	38.414	42.667	47.223	51.589	54.324	56.772	59.717	61.761
43	28.791	30.051	31.970	33.686	35.742	39.363	43.667	48.274	52.686	55.449	57.921	60.884	62.956
44	29.598	30.877	32.824	34.563	36.646	40.312	44.667	49.325	53.782	56.572	59.068	62.059	64.150
45	30.408	31.704	33.678	35.441	37.550	41.262	45.667	50.375	54.878	57.695	60.214	63.231	65.340
46	31.219	32.534	34.534	36.320	38.456	42.212	46.667	51.425	55.972	58.816	61.358	64.402	66.529
47	32.032	33.365	35.392	37.200	39.363	43.163	47.667	52.474	57.065	59.936	62.500	65.571	67.716
48	32.848	34.198	36.250	38.082	40.270	44.115	48.667	53.522	58.158	61.054	63.641	66.738	68.901
49	33.664	35.032	37.111	38.965	41.179	45.067	49.667	54.571	59.249	62.171	64.780	67.903	70.084

the time and accept material with fraction defective $p_2 = .026$ only 10 percent of the time, compute $p_2/p_2 = .026/.01 = 2.6$ and enter Table 2 for $\alpha = .05$ (since $.95 = 1 - \alpha$) and $\beta = .10$ and select the value of the ratio p_2/p_1 in the column for $\alpha = .05$, $\beta = .10$ equal to or just greater than 2.6. The value 2.618 which has associated with it a value of $np_1 = 5.426$ and a value of $c = 9$. The sample size for the desired plan is taken as $np_1/p_1 = 5.426/.01 = 543$ and the acceptance number $c = 9$.

The tables were computed from existing tables of the χ^2 distribution [2, 3] taking advantage of the fact that for even degrees of freedom χ^2 gives the partial sums of a Poisson series [4]. For example, the entry in Table 1 for $c = 5$, $P(A) = .95$ is given by

$$\tfrac{1}{2}\,\chi^2_{P,\,2c+2} = \tfrac{1}{2}\,\chi^2_{.95,\,12} = \tfrac{1}{2}\,(5.22603) = 2.61301$$

where $\chi^2_{P,\,2c+2}$ is the value of χ^2 for $(2c + 2)$ degrees of freedom exceeded with probability P. The value of p_2/p_1 in Table 2 for $c = 5$, $\alpha = .05$, $\beta = .05$ is given by

$$\frac{p_2}{p_1} = \frac{\chi^2_{\beta,\,2c+2}}{\chi^2_{1-\alpha,\,2c+2}} = \frac{\chi^2_{.05,\,12}}{\chi^2_{.95,\,12}} = \frac{21.0261}{5.22603} = 4.02334$$

and the value of np_1 for $c = 5$, $\alpha = .01$ is given by

$$\tfrac{1}{2}\,\chi^2_{1-\alpha,\,2c+2} = \tfrac{1}{2}\,\chi^2_{.99,\,12} = \tfrac{1}{2}\,(3.57056) = 1.78528.$$

The tables are exact if the probability distribution of the number of defectives in a sample of n follows a Poisson law and will, for most prac-

TABLE 2—**Values of np_1 and c for Constructing Single Sampling Plans Whose OC Curve is Required to Pass Through the Two Points $(p_1, 1-\alpha)$ and (p_2, β).**

p_1 is the fraction defective for which the risk of rejection is to be α, and p_2 is the fraction defective for which the risk of acceptance is to be β. To construct the plan, find the tabular value of p_2/p_1 in the column for the given α and β which is equal to or just greater than the given value of the ratio. The sample size is found by dividing the np_1 corresponding to the selected ratio by p_1. The acceptance number is the value of c corresponding to the selected value of the ratio.

	Values of p_2/p_1 for:					Values of p_2/p_1 for:			
c	$\alpha = .05$ $\beta = .10$	$\alpha = .05$ $\beta = .05$	$\alpha = .05$ $\beta = .01$	np_1	c	$\alpha = .01$ $\beta = .10$	$\alpha = .01$ $\beta = .05$	$\alpha = .01$ $\beta = .01$	np_1
0	44.890	58.404	89.781	.052	0	229.105	298.073	458.210	.010
1	10.946	13.349	18.681	.355	1	26.184	31.933	44.686	.149
2	6.509	7.699	10.280	.818	2	12.206	14.439	19.278	.436
3	4.890	5.675	7.352	1.366	3	8.115	9.418	12.202	.823
4	4.057	4.646	5.890	1.970	4	6.249	7.156	9.072	1.279
5	3.549	4.023	5.017	2.613	5	5.195	5.889	7.343	1.785
6	3.206	3.604	4.435	3.286	6	4.520	5.082	6.253	2.330
7	2.957	3.303	4.019	3.981	7	4.050	4.524	5.506	2.906
8	2.768	3.074	3.707	4.695	8	3.705	4.115	4.962	3.507
9	2.618	2.895	3.462	5.426	9	3.440	3.803	4.548	4.130
10	2.497	2.750	3.265	6.169	10	3.229	3.555	4.222	4.771
11	2.397	2.630	3.104	6.924	11	3.058	3.354	3.959	5.428
12	2.312	2.528	2.968	7.690	12	2.915	3.188	3.742	6.099
13	2.240	2.442	2.852	8.464	13	2.795	3.047	3.559	6.782
14	2.177	2.367	2.752	9.246	14	2.692	2.927	3.403	7.477
15	2.122	2.302	2.665	10.035	15	2.603	2.823	3.269	8.181
16	2.073	2.244	2.588	10.831	16	2.524	2.732	3.151	8.895
17	2.029	2.192	2.520	11.633	17	2.455	2.652	3.048	9.616
18	1.990	2.145	2.458	12.442	18	2.393	2.580	2.956	10.346
19	1.954	2.103	2.403	13.254	19	2.337	2.516	2.874	11.082
20	1.922	2.065	2.352	14.072	20	2.287	2.458	2.799	11.825
21	1.892	2.030	2.307	14.894	21	2.241	2.405	2.733	12.574
22	1.865	1.999	2.265	15.719	22	2.200	2.357	2.671	13.329
23	1.840	1.969	2.226	16.548	23	2.162	2.313	2.615	14.088
24	1.817	1.942	2.191	17.382	24	2.126	2.272	2.564	14.853
25	1.795	1.917	2.158	18.218	25	2.094	2.235	2.516	15.623
26	1.775	1.893	2.127	19.058	26	2.064	2.200	2.472	16.397
27	1.757	1.871	2.098	19.900	27	2.035	2.168	2.431	17.175
28	1.739	1.850	2.071	20.746	28	2.009	2.138	2.393	17.957
29	1.723	1.831	2.046	21.594	29	1.985	2.110	2.358	18.742
30	1.707	1.813	2.023	22.444	30	1.962	2.083	2.324	19.532
31	1.692	1.796	2.001	23.298	31	1.940	2.059	2.293	20.324
32	1.679	1.780	1.980	24.152	32	1.920	2.035	2.264	21.120
33	1.665	1.764	1.960	25.010	33	1.900	2.013	2.236	21.919
34	1.653	1.750	1.941	25.870	34	1.882	1.992	2.210	22.721
35	1.641	1.736	1.923	26.731	35	1.865	1.973	2.185	23.525
36	1.630	1.723	1.906	27.594	36	1.848	1.954	2.162	24.333
37	1.619	1.710	1.890	28.460	37	1.833	1.936	2.139	25.143
38	1.609	1.698	1.875	29.327	38	1.818	1.920	2.118	25.955
39	1.599	1.687	1.860	30.196	39	1.804	1.903	2.098	26.770
40	1.590	1.676	1.846	31.066	40	1.790	1.887	2.079	27.587
41	1.581	1.666	1.833	31.938	41	1.777	1.873	2.060	28.406
42	1.572	1.656	1.820	32.812	42	1.765	1.859	2.043	29.228
43	1.564	1.646	1.807	33.686	43	1.753	1.845	2.026	30.051
44	1.556	1.637	1.796	34.563	44	1.742	1.832	2.010	30.877
45	1.548	1.628	1.784	35.441	45	1.731	1.820	1.994	31.704
46	1.541	1.619	1.773	36.320	46	1.720	1.808	1.980	32.534
47	1.534	1.611	1.763	37.200	47	1.710	1.796	1.965	33.365
48	1.527	1.603	1.752	38.082	48	1.701	1.785	1.952	34.198
49	1.521	1.596	1.743	38.965	49	1.691	1.775	1.938	35.032

tical cases, be a satisfactory approximation when the distribution of defectives is binomial [5].

The Tables were computed and checked by Mrs. M. T. Carson of the Statistical Engineering Laboratory, National Bureau of Standards.

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Building a Stable Membership

ELBERT T. TERHUNE

Vice Chairman, National Membership Committee

THIS YEAR, as in years past, the problem of providing sufficient stimulus to reactivate interest among delinquent members continues to be a matter for serious consideration. Obviously, there exists no panacean program which will correct the situation. Any plan of action initiated by the local section necessarily must be tailored to suit its size and the condition of its treasury. However, the following paragraphs contain some general precepts which, if incorporated into a plan adapted to the needs of your section, may provide a means to a more stable membership.

TOP MANAGEMENT

In mapping a campaign designed to incite those members whose interest has flagged, it is well to remember that, when fully convinced of the worth of statistical quality control, members of top management are invaluable allies. The question logically follows: How does one go about convincing a cautious, bargain-conscious businessman that your society offers him and his employees a worthwhile investment? A particularly successful method for accomplishing this end is that of sponsoring meetings directed specifically at the top level of management. In completing arrangements for such meetings, the aid of local Chambers of Commerce often has been enlisted with gratifying results. Announcements, brochures and other literature mailed under their letterhead generally is given more than casual attention by recipients. It has been found that a series of three, four, five or even six letters, beginning several weeks before the scheduled meeting and continuing at intervals of approximately one week, is quite effective in publicizing such a meeting. The speaker for a meeting of this type must, of course, be a man respected for his business achievements as well as a convincing talker and one who is familiar with the results of a sound quality control program.

PROGRAMS FOR REGULAR MEETINGS

If your regular meetings feature a talk on some phase of quality control, your program committee is well-advised to screen the roster of available speakers carefully before issuing invitations. Nothing is as frustrating to new members or potential members as to be subjected to an hour and a half of statistical gobbledygook delivered in a monotone! On the other hand, those members with a more mature knowledge of the subject cannot be expected to evince an avid interest in the rudimentary aspects of statistical quality control. Careful planning to avoid driving members away from meetings is absolutely essential. In addition to the consideration of interesting content, those responsible for selecting a speaker should be assured that he is possessed of one or more of the following: (1) speaking ability, (2) novel or entertaining "props", (3) visual aids. It goes without saying that arranging a yearly program which includes only speakers of this caliber is an almost insurmountable task. Therefore, program committees are advised to consider the feasibility of scheduling several "What's your problem?" sessions during the year; leaders of these discussions to be chosen from among outstanding members of the local section.

TRAINING PROGRAMS

One of the most successful methods of creating and holding interest in the Society has been that of offering an educational program. Such a program must be organized so that it holds forth material suited to the needs of the maximum number of members. In line with this philosophy, it has been found necessary to provide instruction at different levels in order to allow for knowledge differences existing among members. A foremost consideration is that of offering, for beginners, a

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basic course covering the broader aspects of statistical quality control. Suggested topics for this course are items such as (1) frequency distributions, (2) elementary probability theory, (3) introduction to control charting techniques and (4) sampling inspection.

The scope of subjects to be included in additional courses offered will be contingent largely upon the availability of instructional talent. Generally speaking, however, the advanced classes should be utilized to expand on topics introduced in the beginner's group.

Instructors usually can and, if possible, should be recruited from within the section in order that they can be familiar with the problems and personalities of individual members.

PUBLICITY

"It pays to advertise" is a profitable slogan to keep in mind if your membership is lagging. Careful program planning, wonderful training programs—all are for nothing, unless information concerning them is fully disseminated. As mentioned before, local Chambers of Commerce have proven most cooperative in lending their aid and facilities for the purpose of publicizing Society activities. Business editors of local newspapers, too, usually have been willing to devote a few lines of newsprint to announcements of meetings and special events. In addition, the aid of all members should be enlisted to assure that the Society is publicized on the bulletin boards within their own plants.

PERSONAL CONTACTS

The last, and possibly the most important point to be covered, is that of maintaining personal contact with delinquent members. Inasmuch as one of the two qualifications for membership in the Society is, "An interest in quality control," it is logical to assume that every member, potential, active, or delinquent, either has or has had such an interest. The problem, then, is to discover and, if possible, eliminate any reasons for disinterest. Unquestionably, a personal visit is usually the most effective method of reviving a lapsed membership; however, when this is not possible, letters and telephone calls should be utilized. Every effort should be exerted to determine why the member failed to renew his membership. Information obtained should be compiled and screened carefully for clues that indicate areas for improvement in organization and policies of the Section.

SUMMARY

In summarizing, these are but a few of the possibilities that can be exploited to build a firm and stable membership:

(1) Sell top management in your locality on the value of statistical quality control and thereby assure that they will urge their employees to maintain their membership.
(2) Plan regular meetings carefully; don't let them get stale and repetitious.
(3) Provide a useful training program in which members may participate.
(4) Publicize the efforts of your Society.
(5) Contact all individuals who have not renewed. A personal conversation, if possible, should be arranged. In any event, never let a membership lapse unnoticed.

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The goal we are attempting to reach cannot be attained through sporadic membership "drives," though such devices may be used to good advantage. Careful planning, beginning long before the first meeting of the new fiscal year, and enthusiastic, persistent prosecution of these plans are needed to attract new members and to keep them renewing every year.

Bibliography

JOSEPH MOVSHIN, Editor

Assisted by the Editorial Committee, St. Louis Section, ASQC

On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to: Mr. Joseph Movshin, 9220 Old Bonhomme Road, St. Louis 24, Mo.

APPLICATION—CHEMICAL INDUSTRY

Bibliography Section—July 1952

STATISTICAL METHODS IN CHEMISTRY, D. J. Finney.
(Nature, v. 168, n. 4286, Dec. 22, 1951, p. 1072)

At a sectional meeting of the Royal Institute of Chemistry on October 25, 1951, four papers were presented on the "Application of Statistical Methods to Chemistry." These include a discussion on experiment design by Dr. E. C. Wood, choosing a form of curve to represent experimental data, by Dr. D. J. Finney, and a question on the sampling of tablets by Dr. Davies.

This article reviews the discussion and papers of this meeting.

APPLICATION—ELECTRICAL INDUSTRY

QUALITY CONTROL OF TV TUBES, Bertrand W. Squier, Jr., Chief Engineer, Cathode-Ray Tube Dept., Raytheon Manufacturing Company.
(Radio and Television News, v. 47, n. 2, Feb. 52, p. 49)

A description of a production test device for TV cathode-ray tubes.

APPLICATION—MEDICAL AND DRUG INDUSTRY

STATISTICAL QUALITY CONTROL FOR THE DRUG INDUSTRY, R. H. Noel, Director of Product Coordination, Bristol Laboratories, Inc., Syracuse, New York.
(Drug & Allied Industries, v. 38, n. 3, Mar. 52, p. 14)

This is a first of a series of articles in which the author will show examples of Statistical Quality Control as it can be applied to the drug industry. An example of the normal law curve is given along with the simple formulation for determining the standard deviation. Subsequent articles will show to what use characteristics of variability can be put in problems of sampling, in-process control, and process investigation.

CONTROL CHARTS FOR THE DRUG INDUSTRY, R. H. Noel, Director of Product Coordination, Bristol Laboratories, Inc., Syracuse, New York.
(Drug & Allied Industries, v. 38, n. 4, Apr. 52, p. 19)

This is the second of the series of articles by Mr. Noel on the application of Statistical Quality Control in the Drug Industry. This article is a discussion of how the basic fundamentals of control charts can be applied to the problems of process control. This discussion deals primarily with the use of control chart methods. Examples and calculations are presented showing actual control limits used to compare various machines in their operations.

APPLICATION—METAL WORKING

QUALITY CONTROL OF METAL STAMPING, G. M. Bowen and C. M. Smaltz, Feeder and Service Division, Westinghouse Electric Corporation.
(Tooling and Production, v. XVIII, n. 1, Apr. 52, p. 59)

A general discussion of the results of applying various quality controls to metal stamping operations.

APPLICATION—MISCELLANEOUS

QUALITY CONTROL IN HAND PLANTS, Nevin A. Cort, Jr., Bryce Bros. Co., Mt. Pleasant, Pa.
(The Glass Industry, v. 33, n. 4, Apr. 52, p. 193)

A general review of inspection and quality control practices in the glass industry. Reference is made to the use and advantages of control charts. Examples of application include control of breakage and finishing losses.

CALCULATING EXPECTED YARN UNIFORMITY, N. L. Enrick, Werner Textile Consultants, P.O.M. Co.
(Rayon and Synthetic Textiles, April 1952, p. 52)

Mr. Enrick presents an interesting application of the Poisson distribution to the measurement of fiber fineness and yarn uniformity. First, formulas are derived to express the number of fibers per cross section of yarn. The ideal random distributing of this is expressed by the Poisson. The ratio (in %) of the actual to the ideal is called an "Index of Irregularity."

SOME APPLICATION OF STATISTICS FOR AUDITING, John Neter, Syracuse Univ.
(Journal of the American Statistical Association, v. 47, n. 257, Mar. 52, p. 6)

This article discusses the application of statistical methods, especially Quality Control, to auditing. The specific application of statistical methods to three areas of activity of relevance to auditing is reviewd in some detail. These are:

1. Control of clerical accuracy.
2. Sampling accounting records.
3. Sampling physical property.

These suggest techniques that the auditor can use in various other activities.

ENGINEERING AND EXPERIMENTS

A STATISTICAL DISTRIBUTION FUNCTION OF WIDE

APPLICABILITY, Waloddi Weibull.
(Journal of Applied Mechanics, Sept. 1951, p. 293)

From a general form mathematical expression for a distribution function, the author develops several examples of the analysis of unknown distributions. These include:

1. Yield strength of a Bofors steel.
2. Size distribution of fly ash.
3. Fiber strength of Indian cotton.
4. Length of Cyrtoideae.
5. Fatigue life of an ST-37 steel.

The distribution function used is empirically applied and accepted on the basis of being the best information available.

A STATISTICAL APPROACH TO THE MEASUREMENT OF ATMOSPHERIC NOISE, Robert S. Hoff and Raymond C. Johnson.
(Proceedings of the I.R.E., v. 40, n. 2, Feb. 52, p. 185)

A statistical approach to the measurement and description of atmospheric noise using a specially designed measuring and recording equipment. The probability distribution is obtained for each period measured.

MANAGEMENT AND PERSONNEL

HOW TO CUT REJECT COSTS 80%, D. H. Baum.
(FACTORY - Management & Maintenance, v. 109, n. 12, Dec. 51, p. 74)

The Westinghouse use of an employee contest for improvement in cost of rejects in a division making elevator components. A training program was included. Reduction in field adjustment costs are credited to the whole program.

INTERNATIONAL HARVESTER DEMONSTRATES A $10,000,000 QUALITY CONTROL PROGRAM
(Tooling and Production, v. XVIII, n. 1, Apr. 52, p. 72)

The Quality Control System now in operation at 21 International Harvester Company plants is credited with eliminating $10,000,000 worth of labor and material waste. Examples of the savings achieved at various plants are given.
(Also in American Machinist—March 3, 1952)

MISCELLANEOUS

QUALITY CONTROL INDICATORS CUT REJECTS—FAST
(FACTORY-Management and Maintenance, v. 110, n. 1, Jan. 52, p. 128)

Remote control indicators used to maintain continuous control of several inspection operations throughout the plant. These indicators show control as O. K. or rejects too high. The Production Department can take fast action to correct poor production.

THEORY & APPLICATION—GENERAL

HOW TO MAKE QUALITY CONTROL WORK (A Report—Material Prepared by Dr. J. V. Strela, Staff Statistician, Thompson Products, Inc.)
(American Machinist, v. 95, n. 9, April 1951, p. 99)

A lengthy report of the application of Statistical Quality Control at Thompson Products. Discussed are such questions as:

1. What was the Weakness of Early Programs?
2. How do we Train for Quality Control?
3. What is the Place of Quality Control in the Organization?

Discussions of applications include:

1. Quality Control cuts scrap in the Accessories Division.
2. Good dimensional control permits acceptance sampling in Valve Division.
3. Jet Division cuts defects on complex assemblies.
4. Well planned forms save time.

A very interesting table listing nine techniques (charts and sampling plans) is included. The application and purpose of each technique as used is given.

THE BACKGROUND AND BASIS OF QUALITY CONTROL, A. A. Tomkins.
(British Plastics, v. 25, n. 272, Jan. 52, p. 18)

Mr. Tomkins discusses in some detail the general philosophy and background of Statistical Quality Control. Details of the historical background are presented with emphasis on the British rather than the American development. Control by variables is described and illustrated by histograms and charts. Control by attributes is also discussed and the use of the binomial is illustrated in an interesting non-technical manner.

STATISTICS

ABRAHAM WALD, 1902-1950, J. Wolfowitz.

THE FORMATIVE YEARS OF ABRAHAM WALD AND HIS WORKS IN GEOMETRY, Karl Menger.

ABRAHAM WALD'S CONTRIBUTION TO ECONOMETRICS, G. Tintner.

THE PUBLICATIONS OF ABRAHAM WALD.
(The Annals of Mathematical Statistics, v. 23, n. 1, Mar. 52)

The above series of articles are presented in memory of Mr. Abraham Wald, to whom this issue of "The Annals of Mathematical Statistics" is dedicated.

YATES CORRECTION AND THE STATISTICIANS, Franz Adler, University of Arkansas.
(Journal of the American Statistical Association, v. 46, n. 256, Dec. 51, p. 490)

Correction of chi square for discontinuous distribution.

RECENT ADVANCES IN MATHEMATICAL STATISTICS
(Royal Statistical Society Journal, v. 114 (Pt. 4), 1951, p. 497)

CORRECTIONS FOR NON-NORMALITY IN THE USE OF THE TWO-SAMPLE t and F-TESTS AT HIGH SIGNIFICANCE LEVELS, Ralph Allan Bradley, University of North Carolina and Virginia Polytechnic Institute.
(The Annals of Mathematical Statistics, v. 23, n. 1, Mar. 52, p. 103)

ON THE STRUCTURE OF BALANCED INCOMPLETE BLOCK DESIGNS, W. S. Connor, Jr., University of North Carolina.
(The Annals of Mathematical Statistics, v. 23, n. 1, Mar. 52, p. 57)

REPORTED—NOT REVIEWED

ROLE OF STATISTICS AS A TOOL OF MANAGEMENT, J. M. Juran.
(Statistica (Rijswijk), v. 4, n. 1-2, 1950, p. 69)

OUTLINE OF THE PRINCIPLES OF DESIGN AND ANALYSIS OF EXPERIMENTS, D. L. Richards.
(Post Office Electrical Engineers Journal, v. 44, July 51, p. 55)

Book Reviews

A. C. Cohen, Jr., *Editor*

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MATHEMATICS ESSENTIAL FOR ELEMENTARY STATISTICS

Helen M. Walker. Henry Holt and Company, New York, 1951. 382 + xiii pp. $2.10 (cloth). Review by Gayle W. McElrath, Institute of Technology, University of Minnesota.

It is refreshing to find a book styled for adult study including those elementary topics in mathematics which are important to the study of statistical quality control. The emphasis in this revised edition is not only on the presentation for the adult "who once understood but through disuse had forgotten", but also for the adult "who had never understood or perhaps had never studied elementary algebra".

In order to make the material of greatest help to the person who is studying the subject for the first time, the author has been very careful not to assume any previous knowledge of the fundamental concepts. In fact, the first six chapters could easily be labeled "fundamental arithmetic". In these chapters such basic ideas as *order of arithmetic operations, simple operations with common and decimal fractions, placing a decimal point,* and *short cuts in computation* are presented. Included also is a helpful discussion on "How many digits shall I retain in my answer?", a question which is always with the quality control engineer.

In addition to those principles of arithmetic and elementary algebra covered in the book, there are selected topics which might well afford a better understanding and a sense of confidence in the application of quality control techniques. The essential properties of *inequalities* are illustrated by examples exactly parallel to those met in interval estimation. *Linear interpolation* is organized in a manner that would permit the developing of the know-how needed in quality control for the reading of scales and tables. Special attention is given to second degree equations which prove useful in problems of correlation. Chapters on *logarithms, permutations, combinations, the binomial expansion,* and *the multinomial expansion* have been added to this revised edition. The final chapter includes simple discussions on such notions as *spaces of more than three dimensions, sample point, freedom of movement of a point in space,* and *degrees of freedom.* This material is extremely useful for understanding the principles of industrial significance tests and design of experiments.

The reviewer had hoped to see a chapter on elementary probability, probability distributions, and perhaps a chapter on nomographs. In the preface, the author recognizes that she has omitted certain topics essential to a real understanding of statistics. This omission was determined by a desire to keep the book at a reasonable size, and also by the knowledge that many books already exist in which the omitted topics have been adequately presented in an elementary manner.

The book is written to be self-teaching. In keeping with this emphasis, there is an "Initial Test" at the beginning of each chapter. Any one can quickly evaluate his own working knowledge of the material covered and in turn can determine which sections need to be studied. A "Final Test" is included at the end of each chapter to give a measure of accomplishment. There is a complete set of answers for the tests and exercises. The author consistently uses statistical symbols, which serve as a natural introduction to the language of statistics and permit the reader to think in terms of symbols instead of verbal patterns.

This book should be of material aid to quality control personnel who sincerely try to teach themselves the elementary principles of mathematics.

QUALITY CONTROL AND INDUSTRIAL STATISTICS

Acheson J. Duncan, Associate Professor of Statistics, John Hopkins University, 1952; Richard D. Irwin, Inc., 1818 Ridge Road, Homewood, Illinois; 663 + xxvii pp.; $9.00. Review by Joseph J. Moder, Associate Professor, Georgia Institute of Technology.*

Reviewing this book has been indeed a pleasant and educational task. Duncan has done a splendid job of presenting in this volume what is undoubtedly a most comprehensive coverage of both quality control and industrial statistics. The author has shown excellent selection, evaluation, and presentation of the current literature and has conveniently arranged the material for use as a college text, as well as a reference book for industrial research and production personnel.

The material is presented in five relatively independent parts, each of which may well serve as the basis of several courses for engineering or science students at the junior or senior level. For the most part, freshman mathematics would be an adequate prerequisite for this text, which is designed primarily for those interested in the applications of mathematical statistics. However, some use is made of the calculus and a relatively large appendix includes mathematical proofs of many of the theorems stated in the text. Each chapter contains an ample number of problems for teaching purposes, as well as a list of selected references for additional reading.*

Part I, "Fundamentals," covers the fundamentals of probability, construction and interpretation of frequency distributions, the calculation of frequency moments, the Bernouli, Poisson, Normal, and Student's t distributions, and the distributions of means, variances and ranges. This material is presented in a very readable style.

Part I, "Acceptance Sampling by Attributes," Part III, "Acceptance Sampling by Variables," and Part IV, "Control Charts," give a thorough coverage of the conventional statistical quality control subjects. In presenting the material, Duncan has made frequent use of the operating characteristic curve for control charts, as well as accept-

*A "text" price of $6.75 is available only to faculty members, students, and bookstores of collegiate institutions. A Solutions Manual will soon be available to qualified individual purchasers at a price tentatively set at $1.00 and furnished free of charge to instructors using the book in organized classroom work.

ance sampling. The industrial examples used throughout these sections enable the reader to assimilate this material readily.

Part V, "Some Statistics Useful in Industrial Research," covers significance tests, confidence intervals, tests of normality, contingency tables, the analysis of variance, regression and correlation, and experimental design. Again, the author makes frequent use of the operating characteristic curve to show the sensitivity of the tests described. The chapters on significance tests give the needed attention to the most important subjects of calculating sample sizes and experimental design; many useful operating characteristic curves of a general nature are included for this purpose. The chapters on the analysis of variance are extremely well written. One problem is selected for explanation as the subject is developed from the analysis of a single factor through the analysis of three factors. A thorough discussion of the interpretation of the significance tests involved is included.

Industrial research and production personnel will find this book easy to assimilate and extremely valuable as a comprehensive, up-to-date reference book. The price of $9.00* is the only drawback this book has regarding its use as a college text. It is, however, ideally suited to a sequence of courses which would justify its use. Part I lends itself to an introductory course in Engineering Statistics; Parts III & IV to a course in Quality Control, and Part V, to a course in Research Methods.

QUALITY CONTROL AND INDUSTRIAL STATISTICS

Acheson J. Duncan, Associate Professor of Statistics, John Hopkins University, 1952; Richard D. Irwin, Inc. Review by Franklin E. Satterthwaite, Arthur D. Little, Inc., Cambridge, Mass. and General Electric Co., Pittsfield, Mass.

This book is intended primarily as a text for engineering and business students in their second or third year of college. It is also intended to serve as a reference book for quality control engineers and industrial research personnel who seek the aid of modern statistical techniques. With regard to the first purpose, contact with an instructor who has taught engineering statistics for many years brought the comment that this book is better than any previous book he has used for that purpose. Regarding the second purpose, my personal copy of this book stays on top of my desk and is referred to more often than any other text.

The scope of the book includes the fundamentals (117pp.) of probability, frequency distributions, and sampling distributions; includes acceptance sampling (112pp.) by both attributes and variables; includes control chart (95 pp.) theory and practice; includes the statistical methods (230 pp.) of correlation, analysis of variance and the design of experiments as applied to research, development, design, process and industrial enginering problems; includes selected mathematical proofs and technical materia! (46 pp.), and finally includes the best and most convenient set of tables which has yet appeared in any text. Most of the material which the student or the practical engineer will require is to be found in this volume. It is remarkably complete.

The material is well organized and presented. The index is satisfactory, which is a prime requirement for a book of this type. While the presentation is in good mathematical form and no liberties are taken with scientific accuracy, the material is quite readable to the average technically trained person who is many years from academic halls. This book is not recommended to the man without technical training or experience.

Some worthwhile innovations are included which have not generally been included in textbooks heretofore. The material on variables sampling is long overdue. The use of the operating characteristic curve in the analysis of variance is an interesting innovation.

In summary, this is the current textbook of choice for the following groups:

(a) The engineer in industry who is using statistical methods in his daily work.
(b) The undergraduate engineering statistics and quality control course.
(c) The engineer who aspires to (a) and is willing to do a lot of work and study to get there.

The book is not intended as a casual introduction for those not yet using these methods. It is solid meat.

Problems Department

PAUL C. CLIFFORD, Editor

Problems for solution, and correspondence concerning material published in this department, should be addressed to
PAUL C. CLIFFORD
39 Norman Rd.
Montclair, N. J.

Problem 2—Suggested Solutions

Given two small samples of unpaired data, the statistic $1/(\bar{X}_1 - \bar{X}_2)$ is computed. How should the variance of this statistic be estimated?

Joseph M. Cameron of the National Bureau of Standards, Erwin Baumgarten of American Cyanamid, and Paul Stout of the Quaker Oats Company sent in similar solutions to this problem.

If X_1 and X_2 are uncorrelated random variables with variances σ_1^2 and σ_2^2, and with means m_1 and m_2 where $m_1 - m_2 = d$, then under fairly general conditions the variance of $Y = 1/(\bar{X}_1 - \bar{X}_2)$ is given by

$$\frac{\sigma^2}{\sigma_{\bar{y}}^2} = \frac{1}{d^4}\left(\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right).$$

If $\sigma_1 = \sigma_2 = \sigma$, and $n_1 = n_2$, this reduces to

$$\sigma_{\bar{y}}^2 = \frac{2\sigma^2}{nd^4}.$$

The basis for this solution is in the "Theory of Propagation of Errors" discussed, for instance, in Arley and Buch "Probability and Statistics" (John Wiley & Son, New York). Note that the above solution is in terms of population parameters. The estimate $s^2_{\bar{y}}$ will be based on statistics which come from samples, d being estimated from $\bar{X}_1 - \bar{X}_2$ and σ_1 and σ_2 being estimated from s_1 and s_2.

Regarding the general problem of calibration of a balance, Mr. Baumgarten comments:

"The quantity Y is apparently the sensitivity of the balance in mgr/scale divisions, and is determined once and for all as part of the calibration of the balance.

"In view of this interpretation of Y, a word of caution is in order. The variance of Y is in no way related to the variance of an individual weighing. Rather, an error in Y constitutes a bias or systematic error of the balance, remaining fixed until the sensitivity is redetermined. The variance of Y sets a limit on errors in the sensitivity. Only rarely will the true value of the sensitivity differ from its experimentally determined estimate, Y, by more than three σ_Y.

"In order to eliminate the bias resulting from the use of a fixed value for the sensitivity, the sensitivity may be determined anew as part of each weighing: Determine the no-load equilibrium point, $\bar{X}_0$. After placing a load, L, on the L.H.S. and weights, W, on the R.H.S., determine the equilibrium point, $\bar{X}_1$. Add 1 mgr to the R.H.S. of the balance and determine the new equilibrium point, $\bar{X}_2$. Then,

$$L = W + \frac{\bar{X}_1 - \bar{X}_0}{\bar{X}_1 - \bar{X}_2}$$

is a function of random variables $\bar{X}_0$, $\bar{X}_1$, and $\bar{X}_2$ with variance

$$s_L^2 = \frac{2[(\bar{X}_1 - \bar{X}_2)^2 + (\bar{X}_1 - \bar{X}_0)^2]}{(\bar{X}_1 - \bar{X}_2)^4} \cdot \frac{n}{s^2}$$

which reflects the random fluctuations in an individual weighing without bias. Its square root, s_L, can be used for the construction of confidence intervals in the usual manner."

Problem 7

Submitted by Charles Lewis, South Texas Section.

If u and v are normally distributed variables, what is the distribution of uv, u/ v, u^v ?

From the Scrap Box

NOTE ON SQC FILMS

We have been asked to correct for our readers some information incorrectly reported in our January and March issues regarding availability of two SQC films. Accordingly, we give herewith the essential portions of a letter from the Federal Security Agency, Office of Education, which, it is hoped, will clear up this matter for the benefit of all concerned.

"We have been receiving letters, addressed to Commissioner McGrath, requesting the films 'Process Quality Control' and 'Acceptance Sampling,' and we have been told that information designating the U. S. Office of Education as the source of these two films was carried in the January and March issues of your magazine.

"We do not maintain a film library service and do not have prints of either 'Process Quality Control' or 'Acceptance Sampling'—both of which are Navy films. The facts are as follows:

"The U. S. Department of the Navy produced for its own use the two films entitled 'Statistical Quality Control; Process Control' (MN 6621-a) and 'Statistical Quality Control; Acceptance Sampling' (MN 6621-b). Under a cooperative agreement with the U. S. Office of Education, the Department of the Navy in 1951 released these two films for civilian educational use; and the Office of Education, in accordance with established procedures, made the films available for such use through the distribution facilities of United World Films, Inc., New York. (This company holds the overall Government contract for the sale of prints of films, and the Office of Education administers this contract.) Anyone can purchase prints of the two films for these prices: MN 6621-a, $15.86 and MN 6621-b, $24.26.

"In short, 'Process Quality Control' and 'Acceptance Sampling' are Navy films. Neither the Navy nor the Office of Education lends the films. The films can be purchased from United World Films, Inc. They may be rented from 16mm film libraries which have purchased prints."

STATEMENT USED BY McGRAW-HILL PUBLISHING COMPANY IN ANNOUNCING PERIODICAL MICROFILM SERVICE

The McGraw-Hill Publishing Company has entered into an agreement with University Microfilms, Ann Arbor, Mich., to make available to libraries issues of a number of McGraw-Hill publications in microfilm form.

One of the most pressing problems facing all types of libraries today is that of providing adequate space for a const. it flood of publications. Periodicals pose an especially difficult problem because of their bulk and number.

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Under the plan, the library keeps the printed issues unbound and circulates them in that form for from two to three years which corresponds to the period of greatest use. When the paper copies begin to wear out or are not called for frequently, they are disposed of and the microfilm is substituted.

Sales are restricted to those subscribing to the paper edition and the film copy is only distributed at the end of the volume year.

The microfilm is in the form of positive microfilm and is furnished on metal reels suitably labeled. Inquiries concerning purchase should be directed to University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

McGraw-Hill publications covered in the agreement include: AMERICAN MACHINIST, BUSINESS WEEK, CHEMICAL ENGINEERING, COAL AGE, CONSTRUCTION METHODS, ELECTRICAL WORLD, ELECTRONICS, ENGINEERING AND MINING JOURNAL, ENGINEERING NEWS-RECORD, FACTORY MANAGEMENT AND MAINTENANCE, FOOD INDUSTRIES, POWER, PRODUCT ENGINEERING, TEXTILE WORLD, WELDING ENGINEER.

EDITORIAL NOTE: Microfilm editions of IQC *by volumes* are also available from Vol. VII forward through the same agency referenced above. See the May, 1951, issue of IQC, p.95, for further details.

ANOTHER RESPONSE TO "OPERATION BLUEPRINT"

From Ed Schrock of the Lukens Steel Company we have the following contribution.

"Prior to the formation of the American Society for Quality Control, some-

one suggested that ASQC objectives should be concerned with 'The art and science of quality control' rather than just 'The science of quality control.' I have always felt that the omission of the word 'art' from our statement of purpose was a serious mistake. While any worthwhile quality control program will contain much that is scientific, there will also be much that is in the realm of art.

"The following definition indicates the broad field that I feel should be considered as the scope of quality control: 'Modern Industrial Quality Control is the combination of all the devices and techniques that are used to control product quality at the most economical costs which yield adequate customer satisfaction.' The word 'combination' implies coordination of all formal activities relating to the problem of controlling quality. In the past, these have been largely disorganized and carried on with varying degrees of effectiveness in a rather haphazard fashion. The words 'all the devices and techniques' imply much more than simply statistical techniques. They include all the procedures that have been used to control product quality down through the ages as well as the newer statistical techniques. The words 'economical costs' emphasize the fact that this field can help materially in reducing costs as well as improving quality. The words 'adequate customer satisfaction' mean that all this can be done in a way to satisfy our customers so they will want to buy from us again."

Mr. Frank G. Norris of the Wheeling Steel Corporation submits the following comments on the sentiments expressed by Mr. McNair in this column of our January issue:

I hope there will not be much difficulty in convincing the cowboys among us to abandon the Bar-X terminology in favor of the well established X-Bar. One minor point in favor of X-Bar is that the parallel term R-Bar is indeed a mouthful requiring more meticulous attention to proper enunciation than do some of the words cited in Mr. McNair's letter.

Having thus paid tribute to the importance of proper pronunciation of all terms, let me indicate my agreement with a slight amendment of one of the paragraphs, "Until some better name, fully descriptive, is accepted, the full name is to be preferred". The full name "American Society for Quality Control", should not be abbreviated to "American Society" nor augmented to include "Statistical". In the name of our Society and in other familiar titles, it seems logical to conclude that the omission of "statistical" is intentional and not an oversight. As for example, in the title, "The Economic Control of Quality of Manufactured Product", or "A.S.T.M. Manual on Quality Control of Materials."

Let those who encounter difficulty in hasty pronunciation of "statistician" reflect on the relative disadvantage of the "spectroscopist".

Use of "statistical" to avoid popular misunderstanding is likely to lead to more misunderstanding that it avoids.

Statistics to the layman means anything from mortality statistics to tables of the production of bananas in Hyderbad; or more to the point, "The Production of Steel in Great Britain in 1951". This source of slight confusion is less difficult to overcome than is the fact that people have been controlling quality for forty years. In fact this historical background of Quality Control may be recommended on the grounds of the pedologically sound procedure of starting from the known rather than jumping headlong into the unknown subject of statistics.

THE PROBLEM OF NOTATION IN STATISTICAL QUALITY CONTROL

C. C. CRAIG
University of Michigan

It is a matter of common knowledge that the situation with respect to notation in statistical theory and methodology was confused enough even before the advent of statistical quality control. There were already too many different symbols and names for the same things in use and there were still individuals, usually new to the field, who freely invented new symbols and names instead of bothering to learn and use those which had some prospect of becoming standard. Though the existence of various vested interests, indifference, and even personal feuds made it seem hopeless to expect that by any widely concerted action a standard statistical notation could be formally adopted in the near future, nevertheless there had been in recent years a tendency toward greater standardization which many individual statistical writers have tried to help along. The real pioneers in that late-comer among fields of applications of statistical methods, statistical quality control, notably Shewhart in his "Economic Control of Qualtiy of Manufactured Product," used notation already in good standing in the literature. But in the early forties there came forth the ASTM Manual on the Presentation of Data and then the famous War Standards, Z1.1, Z1.2 and Z1.3 of the American Standards Association with some unnecessary new and clumsy statistical notation which has recently been adopted as standard by a committee of the American Society for Quality Control.

To be fair I must admit that actually no greater number of symbols have been improvised in Statistical Quality Control in place of those already in existence. This can be regarded as fortunate; what is less fortunate is the isolationist spirit which has so far been exhibited in this matter. Statistical quality control as a science is still only one of the fields of applications of appropriate portions of theoretical statistics. Its most rapid, sound, and effective growth will only take place by drawing freely from the store of knowledge and tools provided by statistical science in general. For example, the analysis of variance is coming into its own as a powerful method for quality investigations but it was developed by theoretical statisticians for agricultural applications. Again, sequential analysis was developed for receiving inspection by a professor of mathematical statistics. It is not irrelevant to remark that the men who are now developing the Canadian mining frontier are not restricting themselves to the tools that can be brought in by one pack train nor to the knowledge that can be picked up on location.

It seems to me of first importance that we should not make it more difficult for students who have received good general statistical training to enter the field of statistical quality control nor for people already in statistical quality control to increase their knowledge of useful statistics by throwing up a notational barrier. The objectives in studying the problem of standardization of notation in statistical quality control should include a very serious effort to avoid the creation of such a hurdle.

So far I have said nothing about the statistical quality control symbols I personally object to. I don't intend to go over the report of the committee in detail. But the worst case is the use of primes to indicate universe or population parameters, a practice unique to statistical quality control. It is an excellent idea, whose merits have been recognized for some time, to distinguish sample values from population values. But the system which had gained wide and growing acceptance was to use Greek letters for population values and the corresponding Roman letters for the like sample quantities. I have heard the objection that a half dozen Greek let-

ters are too much for SQC people. They already tolerate σ but perhaps that is about the limit. I cannot take this very seriously; the people who are really going to make SQC work are not going to be bothered by difficulties at that level. They will be people who have learned enough about statistics to realize what a gain it would be if the confusion of tongues at the statistical tower of Babel could be removed.

I deplore primes as messy and confusing to write, and unnecessary anyway. I deplore a kind of insularity that seems not at all concerned at building a separate kingdom cut off from the rest of the statistical world. I don't think the American Society for Quality Control really wants this kind of a development at all. Rather we should join up and benefit ourselves by assisting and not hindering what can be done to make scientific statistics one world.

U.S. NAVAL ENGINEERING EXPERIMENT STATION
ANNAPOLIS MARYLAND

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47	NOV.	48	MAR.
MAR.	48	NOV.	47
48	MAR.	47	NOV.

(SEAL)

SIGNED *Bruce B. Day*
THE CONFOUNDING ZERO ORDER INTERACTION

The above "diploma" was submitted by Francis R. DelPriore of the Baltimore Section. It is used to members of the statistical seminar conducted at the U.S. Naval Engineering Experiment Station by the Statistical Office. The seminar is an annual affair, running about 15 weeks, 1½ hours per week, with around 18 engineers in attendance. This in-training course introduces the technical staff to the concepts and use of statistics as a regular working tool. Particular stress is made on statistical design of experiments as well as analysis of results.

AMERICAN SOCIETY NEWS

OUR EVER-GROWING FAMILY

After some two years of operations as a Sub-Section of the Boston Section, Worcester became the 57th Section of the Society on May 19, 1952, with President Weaver participating in the inaugural meeting. A former National Director of the Society, Mr. Charles J. Hudson, The Norton Company, Worcester, Mass., is the first Chairman of this new group. Other officers are as follows: *Vice Chairman*—Clesson Robbins, American Optical Co., Southbridge, Mass. *Secretary*—Arthur P. Pingalore, Telechron Division of General Electric Company, Ashland, Mass. *Treasurer*—Warren Arnold, Jr., Draper Corp., Hopedale, Mass. *National Director*—Axel U. Sternloff, American Steel & Wire Company, Worcester, Mass.

On May 21, 1952, the Executive Committee approved the petition of the Evansville, Indiana group—operating under a tentative arrangement—to grant full Section status to the Evansville-Owensboro Section as the 58th Section of the Society.

Officers at the time full Section status was granted were as follows: *National Director*—James W. Fo-

drea, Chevrolet-Muncie Division, GMC, Muncie, Ind. *Chairman*—George H. Johnson, Warner Gear Division, Borg-Warner Corp., Muncie, Ind. *Vice-Chairman*—Carleton McCray, Chevrolet-Muncie Division, GMC, Muncie, Ind. *Secy.-Treasurer*—Robert L. Smith, Broderick Company, Muncie, Ind.

The Utica Section became the 59th Section of the Society, also approved on May 21, 1952. Officers are as follows: *National Director*—R. B. Griffith, Bossert Company, Utica, N. Y. *Chairman*—W. K. Wood, Brunner Manufacturing Co., Utica, N. Y. *Vice Chairman*—James P. Heywood, Receiver Works of General Electric Company, Utica, N. Y. *Secretary*—J. L. Pauly, Bendix Aviation Corp., Utica, N. Y. *Treasurer*—F. H. Mathewson, Utica Drop Forge Company, Utica, N. Y.

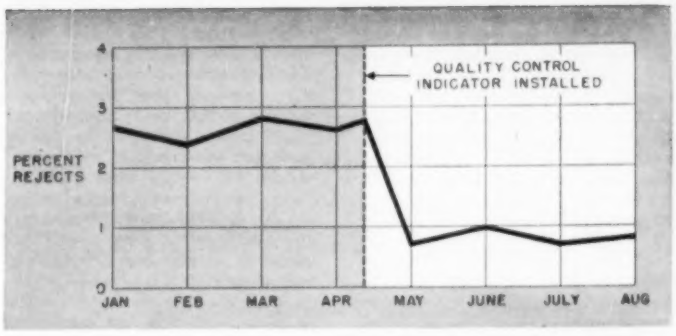
The Society is glad to welcome these new Sections and the new members they bring into our family.

EXECUTIVE COMMITTEE MEETS

A meeting of the Executive Committee of the Society was held preceding the Convention in Syracuse on May 21, 1952. Two actions of considerable importance to the future development of the Society were taken at that meeting.

The publications activities of the Society have expanded to about the limit that can be expected to be handled by the voluntary contribution of time by the several individuals involved. As our Society continues to grow it is mandatory that these activities keep pace with that growth. After careful study of the problem, the Executive Committee authorized the establishment of a publications office in Milwaukee, managed by a full-time, salaried Managing Editor, and has retained Mr. George R. Foster in that capacity effective September 1, 1952. The Annual Report of the Chairman of the Editorial Board, which will appear in the September issue, will carry more complete details.

The extremely broad field of interests covered by our membership has evidenced increased recent expansion. But so, also, has our membership concentration in certain general industrial fields increased. This has created a demand for organization by fields of general interest, as is so common among technical socie-



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GENERAL ELECTRIC

ties. The Executive Committee recommended that the Board of Directors approve the establishment of "Divisions" within the Society, such Divisions to be composed of any ASQC members who desire to affiliate, and to operate completely within the framework of the existent constitution of ASQC. (The Board of Directors has subsequently endorsed both of the foregoing items.)

TEXTILE DIVISION—ASQC

As a result of the action by the Board of Directors authorizing the establishment of Divisions, the initial venture in this area will be the Textile Division. Activities of the Textile Technical Committee have for some time been directed toward the holding of a Textile Conference in Clemson, S. C., late in August, 1952.

Plans are now under way to formalize the Textile Division at the time of that Conference. All ASQC members interested in affiliating should contact Mr. E. G. Field, E. G. Field & Associates, 1101 Hurt Building, Atlanta 3, Ga.

ASQC RECEIVES CERTIFICATE OF COOPERATION FROM ECONOMIC COOPERATION ADMINISTRATION

The following letter announces the award of a certificate of cooperation to ASQC by ECA:

"We take pleasure in forwarding to you the Certificate of Cooperation in recognition of the courtesy extended by you to individuals on technical assistance missions from Western European countries. Your cooperation in receiving these managers, technicians and workers from Western European countries has made you an important partner in the effort to bring strength to the free world. This Certificate is a token of our gratitude and appreciation for assisting foreign visitors in gaining a better understanding of the United States economy, and thus giving them a new realization of what they must do—each in his own industry — to build up the defensive strength of their countries. Generous and unstinting aid, such as you have given, is helping to make the Productivity Assistance Program a powerful factor in the strengthening of Western Europe.

"It may interest you to know the role the Productivity and Technical Assistance Program is playing in the overall effort to make the countries of Western Europe strong enough to resist Communist aggression. By their own strenuous efforts, and through the help given them by the United States, most of these countries are now producing considerably more than they did in pre-war years. But even this increase in their productive capacity is not enough to support the all-out armament effort they are now undertaking. In most of these countries there are no new resources to be tapped; the production increase must, therefore, come out of the better utilization of existing plant, equipment and manpower. It is precisely in this field, i.e., the most effective utilization of plant equipment and manpower, that the United States leads the world. The knowledge which our European allies are seeking for our mutual security, can best be learned in the United States and from organizations such as yours.

"We wish you would convey to the members of your organization the gratitude which all of us feel for the splendid way in which they are cooperating to make the Productivity and Technical Assistance Program a success, and in so doing helping the mutual effort to strengthen the defenses of the free nations."

WALD MEMORIAL FUND

As a tribute in memory of the late Professor Abraham Wald, who was killed with Mrs. Wald in an airplane accident in India, December 13, 1950, a group of friends and colleagues are establishing a fund to help in defraying the expenses of a college education for his two children, Betty, eight years old, and Bobby, now four. Professor Wald will be best remembered by the members of this society for his development of the theory of sequential sampling, which has proved such a valuable statistical tool.

Trustees of the fund are Theodore W. Anderson, Howard Levene, and Mortimer Spiegelman. Contributions may be made payable to WALD MEMORIAL FUND and may be sent to Howard Levene, Box 23 Fayerweather, Columbia University, New York 27, New York.

CONSULTING SERVICES

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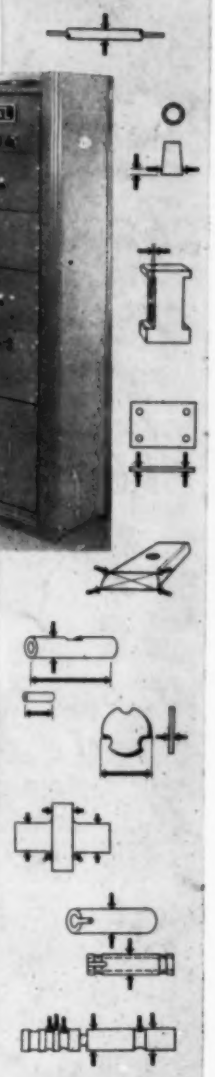

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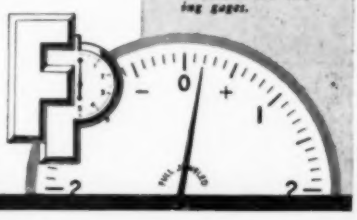
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